Threatened bryophytes of the neotropical rain forest: a status report

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Abstract. Tropical deforestation, inevitably, leads to the local loss of bryophyte species. Recent studies show that the degree of species loss may vary considerably and depends on the scale or amount of habitat change that has occurred. Predictably, the shade epiphytes are most seriously affected by disturbance. An estimated 10% of the bryophyte species of neotropical rain forests are under threat. Based on data from recent monographs, a first list of 19 endangered and 27 rare species of these forests is presented. Critical areas for threatened species include Costa Rica and Panama, the Greater Antilles, the Chocó, southeastern Brazil, and parts of Amazonia. Protection of as much as possible of the remaining natural rain forest area seems the best approach to the conservation of the tropical bryophyte flora.

Bryophytes are an important component of the tropical rain forest (broadly defined here to include both the lowland and montane forest types of Richards 1952). In the neotropics probably an estimated 1500+ species occur in the rain forest, which amounts to more than half of the total neotropical bryophyte flora.

Tropical forests are now disappearing rapidly. Recent estimates by the Food and Agriculture Organization (FAO) of the United Nations indicate that almost half have already gone and that the remainder are disappearing at a rate of about 1% per year (Groombridge 1992). Deforestation is particularly alarming in areas with rapid population growth such as the Philippines, Indonesia, Sri Lanka, India, Madagascar, West Africa, the Atlantic coast of Brazil, and Central America (Table 1; Fig. 1). The rate of loss is so rapid that the view has been expressed that a significant proportion of all species of plants and animals of the tropical rain forest are likely to become extinct in the next few decades (see Whitmore and Sayer 1992).

Bryologists are becoming increasingly aware of the threatened status of the tropical bryophyte flora and resolutions expressing concern about this have been adopted at various recent conferences (e.g. Geissler and Greene 1982, Tan et al. 1991). It is therefore disturbing to note that, to date, almost nothing has been published about the actual impact of rain forest destruction on bryophytes. For my recent review of the subject (Gradstein 1992) I was able to find only three papers, two dealing with Papuan bryophytes (Hyvönen et al. 1987, Norris 1990) and one with bryophytes of Mt Kilimanjaro (Pócs 1992 and personal communication). In the neotropics the subject apparently remains completely uninvestigated.

The reason for this lack of data is obviously not

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>REMAINING (1983) PRIMARY FOREST (km²)</th>
<th>CURRENT ANNUAL RATE OF FOREST LOSS (km²)</th>
<th>% OF 1983 COVER LOST ANNUALLY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nicaragua</td>
<td>27,000</td>
<td>1,000</td>
<td>3.7</td>
</tr>
<tr>
<td>Guatemala</td>
<td>25,700</td>
<td>600</td>
<td>2.3</td>
</tr>
<tr>
<td>Panama</td>
<td>21,500</td>
<td>500</td>
<td>2.3</td>
</tr>
<tr>
<td>Honduras</td>
<td>19,300</td>
<td>700</td>
<td>3.6</td>
</tr>
<tr>
<td>Costa Rica</td>
<td>15,400</td>
<td>600</td>
<td>3.9</td>
</tr>
<tr>
<td>Belize</td>
<td>9,750</td>
<td>32</td>
<td>0.3</td>
</tr>
<tr>
<td>El Salvador</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Central America</td>
<td>118,650</td>
<td>3,432</td>
<td>2.9</td>
</tr>
</tbody>
</table>


Table 2. Threatened bryophytes of the neotropical rain forest. For brevity coauthors of references are indicated by a stroke.

<table>
<thead>
<tr>
<th>Species</th>
<th>Distribution</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brymela tutezona Crosby &amp; Allen</td>
<td>Panama: Veraguas</td>
<td>Crosby/ 1985</td>
</tr>
<tr>
<td>Calypogeia rynchophylla (Herz.) Bischl.</td>
<td>Costa Rica</td>
<td>Morales 1991</td>
</tr>
<tr>
<td>Campylopus atlanticus Allen</td>
<td>Panama</td>
<td>Allen 1990a</td>
</tr>
<tr>
<td>Dactylolejeunea acanthifolia Schust.</td>
<td>Dominica</td>
<td>Schuster 1970</td>
</tr>
<tr>
<td>Drepanolejeunea aculeata Bischl.</td>
<td>SE Brazil</td>
<td>Bischler 1964</td>
</tr>
<tr>
<td>D. senticosa Bischl.</td>
<td>Cuba: Oriente</td>
<td>ibid.</td>
</tr>
<tr>
<td>D. spinosa Herz.</td>
<td>Colombia: El Valle</td>
<td>ibid.</td>
</tr>
<tr>
<td>Fissidens hydropogon Spruce</td>
<td>Ecuador: Bombonasa</td>
<td>Pursell/ 1988</td>
</tr>
<tr>
<td>Fulfordiantus evansii (Fulf.) Gradst.</td>
<td>Central America</td>
<td>Gradstein 1992a</td>
</tr>
<tr>
<td>Leptolejeunea tridentata Bischl.</td>
<td>Colombia: Chocó</td>
<td>Bischler 1969</td>
</tr>
<tr>
<td>Myriocolea irrigata Spruce</td>
<td>Ecuador: Rio Topo</td>
<td>Spruce 1984</td>
</tr>
<tr>
<td>Nowellia reedi Robins</td>
<td>Costa Rica</td>
<td>Robinson 1970</td>
</tr>
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<td>N. wrightii Grolle</td>
<td>Cuba: Oriente</td>
<td>Grolle 1968</td>
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<tr>
<td>Phycolepidozia exigua Schust.</td>
<td>Dominica</td>
<td>Schuster 1966</td>
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<td>Plagiochila wolframi Inoue</td>
<td>Northern Peru</td>
<td>Inoue 1987</td>
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<td>Sphaerolejeunea umbilicata Herz.</td>
<td>Colombia: Caucan</td>
<td>Herzog 1938</td>
</tr>
<tr>
<td>Spruceanthus theobroma (Spruce) Gradst.</td>
<td>Ecuador: El Rios</td>
<td>Gradstein in press</td>
</tr>
<tr>
<td>Syrrhopodon isthmi Reese</td>
<td>Panama: Cerro Jefe</td>
<td>Reese 1992</td>
</tr>
<tr>
<td>S. theriotii Bartr.</td>
<td>Costa Rica</td>
<td>Reese 1992</td>
</tr>
</tbody>
</table>
a lack of interest in the subject. Rather, it would seem that attempts to evaluate the problem are hampered by a serious lack of information on the taxonomy, distribution and ecology of tropical bryophyte species. Large rain forest areas of tropical America remain poorly explored bryologically, including portions of the Amazon basin, the Pacific coastal forests of northwestern South America and the remnants of the Central American rain forest, while many bryophyte genera have not been monographed. However, as shown by Buck and Thiers (1989) and Gradstein (1991), the number of monographs and regional floras published or in preparation is now increasing and more and more information is becoming available on the ranges of rain forest species. For an evaluation of the rarity of species and the degree to which they are threatened, these publications are an indispensable source of information. There is also a growing literature on the ecology of rain forest bryophytes (Frahm and Gradstein 1990).

In this paper I have tried to evaluate the impact of tropical deforestation on bryophytes and to identify rare and endangered species based on recently published taxonomic, phytogeographic and ecological data. For the reasons given above, my treatment must be considered preliminary. Nevertheless, I have found it a challenge to deal with a subject on which so little has been published. I hope that this paper will stimulate bryologists, especially those living or stationed in the tropics, to tackle this much neglected field of research.

Impact of deforestation

In a dense, undisturbed rain forest bryophytes usually do not grow in a random fashion. Different species are found on tree bases, trunks, branches, twigs or leaves, or on logs in various stages of decay (Pócs 1982, Richards 1984), due to subtle differences in the ecological conditions of the substrate: water supply, light, nutrients, etc. Moreover, some species occur exclusively in the moist, shaded understorey of the forest and inner canopy whereas others are only found in the drier, outer portions of the canopy high above the ground. Following Richards (1954, 1984), these two ecological species groups may be called “shade epiphytes” and “sun epiphytes”, respectively. They are ecological “specialists”. In addition, “generalists” with wide vertical distributions have been recorded. In the rain forests of the Guianas, the following species belonging to these categories have been recorded (after Richards 1954, Cornelissen and Ter Steege 1989, Montfoort and Ek 1990, Cornelissen and Gradstein 1991):

**SHADE EPIPHYTES**

Archilejeunea parviflora  
Callicosta bipinnata  
Callicostella rufescens  
Calymperes platyloma  
Calypogeia spp.  
Cololejeunea appressa  
Crossoptilejeunea boryana  
Fissidens spp.  
Glossadelphus truncatulus  
Haplolejeunea cucullata  
Hoekeriopsis parkeriana  
Lejeunea caespitosa  
Lepidopilum surinamense  
Leptolejeunea exocellata  
Leucobryum martianum  
Leucoloma cruegerianum  
Leucophanes mittenii  
Lophocolea spp.  
Lopholejeunea muelleriana  
Micropterygium trachyphyllum  
Mniomalia viridis  
Octoblepharum pulvinatum  
Pictolejeunea picta  
Phyllocrepipodium falcifolium  
Pilosium chlorophyllum  
Plagiochila laetevirens  
Porotrichum plicatum  
Prionolejeunea spp.  
Racopilopsis trinitensis  
Riccardia amazonica  
Sematophyllum subsimplex  
Sitcotelejeunea balfourii  
Syrhopodon circinnatum  
S. cryptocarpos  
S. incompletus  
S. ligulatus
What are the consequences for bryophytes when the rain forest is damaged or destroyed? Hyvönen et al. (1987) compared the bryophyte flora of virgin rain forest in Papua New Guinea with that of moderately disturbed vegetation in the same general area: depleted forest, secondary growth, and slash-and-burn agricultural fields. They found that the bryophyte flora of the disturbed habitats was quite luxuriant and scarcely poorer in species than the virgin forest. The flora of the disturbed habitats included “newcomers”, which were absent from the dense forest, as well as “stayers”, which occurred in both areas. Newcomers were mainly weedy, ruderal species characteristic of man-made environments. The stayers included species that had become rarer in the disturbed areas, and those that had become more common. About 30% of the species of the undisturbed forest were lacking in the disturbed areas.

Very different results were obtained by Pócs (personal communication) in the course of a study on Mt Kilimanjaro, Tanzania. He compared the bryophyte flora of virgin rain forest on the lower slopes of the mountain with that of a plantation of exotic tree species in the same area. Only 10% of the forest species reappeared in the plantation and thus 90% of the rain forest flora had become lost! Depletion of the rich habitat diversity of the primary forest, as well as the predominance of fast-growing tree species in the plantation, seemed to be important reasons why bryophyte species of the rain forest had been unable to re-establish themselves in the plantation.

The above studies indicate that the floristic changes due to deforestation are dependent on the amount of damage inflicted upon the forest. In monocultures and other areas with large-scale farming methods and total clearance of the forest, the forest flora is much more impoverished than in areas of shifting cultivation and small-scale damage to the forest.

The studies also show that the shade epiphytes of the forest undergrowth are more seriously affected by the disturbance than the sun epiphytes. The former are, predictably, less well adapted to desiccation and are the first to disappear when the forest canopy is opened up. The sun epiphytes, on the other hand, are adapted to
relatively dry habitats and are, predictably, more capable of surviving in disturbed areas. They may "come down" from the canopy in the opened-up areas and establish themselves nearer to the ground in secondary habitats. Generalists may also be expected to survive disturbance.

Examples of sun epiphytes which, in the neotropics, are very common near ground level in secondary growth, scrub, orchards or on fallen trees include Acroporium pungens, Frullania spp., Leucodontopsis gericulata (= Henicodium gericulatum), various Lejeuneaceae (Acrolejeunea, Ceratolejeunea spp., Cheilolejeunea, Frullanoides, Lopholejeunea sub fusca and Mastigolejeunea auriculata), Orthostichopsis tetragona, Papillaria nigrescens, and the Orthotrichiaceae: Gouttiella, Schlotheimia and Macromitrium spp.

Summing up, the available data lead to the following conclusions:

1. Tropical deforestation, inevitably, leads to the local loss of bryophyte species. The degree of the loss may vary considerably and depends on the scale or amount of habitat change that has occurred.

2. Predictably, the shade epiphytes are most seriously affected by disturbance.

**Threatened species**

No bryophyte species has as yet been reported as extinct in the neotropics. However, one would expect that quite a number of species, in particular rare and endemic ones, are threatened with extinction as the forest vanishes. Table 2 lists 46 species (18 mosses, 28 hepatics) which I have identified as threatened. The selection of the taxa was made according to the following criteria:

1) The species should be narrowly endemic or more widely distributed but nowhere common. They should be restricted to the neotropics and rare on a world-wide scale.

2) The species should occur exclusively in undisturbed rain forest (broadly defined here and including montane cloud forests), and be unable to re-establish themselves in secondary vegetation. Most of the species that fit this criterion are shade epiphytes.

3) The taxonomic status and distribution of the species must have been verified by a specialist, preferably in a monograph.

Based on an estimated 1500 neotropical rain forest bryophyte species, the present list represents about 3.5% of the forest flora. Since only about 20-30% of rain forest species have been monographed, the list represents only a small portion of the threatened flora. Many rare taxa, known from only 1-2 collections, are still of doubtful taxonomic status, e.g. members of the Hookeriae, Lejeuneoideae, Plagiochilaceae, Pterobryaceae, Radulaceae and Sematophyllaceae. Revision of these groups will undoubtedly reveal further threatened taxa. (*)

Within the families of neotropical rain forest bryophytes that have been monographed, the number of threatened species varies considerably and is about 1% in the Fissidentaceae, 8% in the Neckeraceae, 10-15% in the Lejeuneaceae and 20% in the Calymperaceae. The figures indicate that it is difficult to determine the total number of threatened species. Based on the above data, I estimate that about 10% of the bryophyte species of neotropical rain forests are threatened. This would amount to about 150 species or three times the number listed in Table 2.

In order to establish the status of those species and to qualify the degree of threat, I have applied the IUCN Red Data Book categories as defined by Mori and Prance (1990) in their monograph of neotropical Lecythidaceae. I have been able to recognize the following categories:

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(*) Dr. Angela Newton (pers. comm.) has recently found several species of the genus *Pireella* (Pterobryaceae) with very limited distributions. Two species are known only from a single locality and may be considered endangered: *P. falcifolia* Bartr. (Guatemala) and *P. gemmescens* Robins. (Ecuador).
2. RARE SPECIES

*Adelanthus squarrosus* Grolle
*Arachnoptis pecten* Spruce
*Blepharolejeunea saccata* (Steph.) Slag. & Kruijt
*Calypomeres mitrafugax* Florsch.
*C. platyloma* Mitt.
*D. smithii* Bartr.
*Campyloopus gemmatus* (C.Müll.) Par.
*Crossomtrium acuminatum* Bartr.
*Drepanolejeunea bischleriana* Porto & Grolle
*D. evansii* Bischl.
*Haesselia roraimensis* Grolle & Gradst.
*Naplomitrium andinum* (Spruce) Schust.
*Jubula bogotensis* Steph.
*Leucomium steerei* Allen & Veling
*Lopholejeunea quelchi* Steph.
*Mastigolejeunea innovans* (Spruce) Schiffn.
*Neurolejeunea catenulata* (Nees) Schiffn.
*Pictolejeunea sprucei* Grolle
*Plagiochila cucullifolia* Jack & Steph.
*Renaudia paradoxica* Allen
*Sematophyllum pacimoniense* (Mitt.) Florsch.
*Symbiesidium dentatum* Herz.
*Syrhopodon elatus* Mont.
*S. erubescens* Bartr.
*S. fimbriatus* Mitt.
*S. flexifolius* Mitt.
*S. helicophyllus* Mitt.

Guyana: *Roraima* Grolle 1989
N *Amazonia, Guianas* Gradstein/ 1989
Neotropical *Slageren/ 1985*
N *Amazonia, Guianas* Reese 1992
Amazonia, *Guianas* ibid.
Amazonia, *Guianas* ibid.
SE Brazil *Frahm 1991*
C *America, Chocó* Allen 1990
*Eastern Brazil* Schäfer 1989
Antilles *Bischler 1964*
Guyana: *Roraima* Barthol. 1991
Neotropical *Grolle/ 1988*
Neotropical *Guercke 1974*
Guayana, *SE Brazil* Schäfer 1992
Antilles, *Guianas* Gradstein in press
C *Amazonia, Guianas* Gradstein in press
Antilles *Gradstein in press*
Brazil: *Amazonia* Gradstein in press
C *America, Colombia* Gradstein MS
Mt *Roraima, Panama* Gradstein/ 1989
N *Amazonia, Surinam* Florschütz 1992
Chocó *Gradstein/ 1985*
Amazonia, *Guianas* Reese 1992
C *America, Puerto Rico* ibid.
Amazonia *ibid.*
N *Amazonia, Costa Rica* ibid.
Northern *Amazonia* ibid.
1. **Endangered species.** This category includes narrowly endemic species known from a few (1-3) localities, in areas undergoing rapid deforestation. Neotropical areas where deforestation is most alarming at present include Mexico and Central America (Fig. 1; Table 1), the Caribbean, the Pacific coast of northern South America, especially Ecuador, western, eastern and southern portions of the Amazon basin, the Andes, and the Atlantic coast of Brazil (see Myers 1983, Groombridge 1992).

2. **Rare species.** This category includes narrowly endemic species known from areas which are not threatened with immediate deforestation, such as inner Amazonia and the Guianas, and neotropical species occurring over a wider range but nowhere common. The number of localities of species included in this category should be less than 10.

Mori and Prance (1990) also recognized “**Vulnerable Species**”, which are less threatened than the Endangered ones (at least at present) because of their occurrence in protected areas. Since the occurrence of bryophyte species in neotropical forest reserves is poorly documented, I have not been able to apply this criterion in my evaluation.

Based on the above categories, I have been able to recognize **19 endangered** and **27 rare** species of neotropical rain forest bryophytes. The group of rare species is, admittedly, somewhat heterogeneous as it includes species known from only one locality, e.g. the Roraima endemics *Adelanthus squarrosus* and *Haesselia roraimensis*, as well as rather widespread neotropical taxa such as *Blepharolejeunea saccata*, *Haplomitrium andinum* and *Jubula bogotensis*. The number of recent records of these widespread taxa is so small (most of the collections are from the 19th century!), however, that I have not hesitated to include them in the list of threatened species.

Several remarkable, phylogenetically isolated taxa are among the threatened species. *Dactylolejeunea acanthifolia*, *Myriocolea irtorata*, *Phycolepidozia exigua*, *Sphaerolejeunea umbilicata* belong to monotypic genera while *Calypogeia rynchophylla*, *Blepharolejeunea saccata* and *Plagiochila cucullifolia* represent monotypic subgenera. *Brymela tutezona*, *Fissidens hydrotopogon*, *Arachniopsis pecten*, *Haesselia roraimensis*, *Nowellia reedii* and *Drepanolejeunea bischleriana* are also morphologically unusual within the genera to which they belong. Other important species are *Haplomitrium andinum*, *Jubula bogotensis*, *Renaudia paradoxica* and *Spruceanthus theobromae*, which are the only neotropical representatives of the genera and are thus of considerable phytogeographical interest. Details concerning the morphology and localities of the threatened taxa will be found in the papers listed in Table 2.

Further exploration of underexplored areas may reveal that some species listed here as threatened are in fact more common than currently known. The Chocó endemics *Fulfordianthus pterobryoides* and *Luteolejeunea herzogii*, for example, were listed as rare species in a draft version of this paper based on information on their distribution provided in recent monographs (Gradstein 1992a, Piippo 1986). However, during my travels in the Chocó Department (Colombia) in the summer of 1992, I found that they were very common in the area and occurred in both primary and secondary forest. Therefore, I have excluded them from the list. Other discoveries and new monographs may necessitate further changes.

Based on the distribution of the threatened species, the following areas can be identified as the most critical for threatened neotropical rain forest bryophytes:

1) **Costa Rica and Panama.**

This area has six endangered species or the largest concentration of endangered taxa in a single area: *Brymela tutezona*, *Calypogeia rynchophylla*, *Campylopus atlanticus*, *Fulfordianthus evansii*, *Nowellia reedii*, *Syrrophodon isthmi*, and *S. theriotii*.

2) **The Pacific coast of Ecuador and Colombia and the adjacent western slopes of the Andes.**

This area, known as the “Chocó Phytogeographic province” (Gentry 1982), has nine threatened species, including three endangered ones:
Drepanolejeunea spinosa, Leptolejeunea tridentata, and Sphaerolejeunea umbilicata. As shown below, large parts of the Chocó are still bryological “terra incognita” and future exploration of this area may well lead to changes in the list.

3) Inner and northern Amazonia, including Guayana.
This is the neotropical centre of endemism for rain forest species and 17 of its endemic species have been identified as threatened (Table 2). Since deforestation in most portions of this area is not (yet) alarming, the threatened Amazonian taxa are usually classified as rare. An exception are two endemic species of Amazonian Ecuador, Fissidens hydropogon and Myriocolea irrorata, which are classified as endangered because the forest in the area is under considerable pressure. Both species were discovered by Richard Spruce around the middle of the 19th century and have not been collected since. Hopefully they are not extinct!

4) The Greater Antilles.
Five threatened species occur on the islands of the Greater Antilles. A particularly critical area is eastern Cuba, which has two endangered taxa: Drepanolejeunea senticosa and Nowellia wrightii. It is also the only area from which the rare Neurolejeunea catenulata has been collected in recent years.

5) Southeastern Brazil.
The rain forest remnants along the Atlantic coast of southeastern Brazil harbour four threatened species, including the endangered Drepanolejeunea aculeata. Another very rare endemic of this area is Campylopus gemnatus, which is known from only three or four localities. The continued existence of this species seems safeguarded, however, by its occurrence in Mt Itaiaia National Park. The species should therefore not be considered endangered (A. Schäfer-Verwimp, personal communication).

Because of their small size, bryophytes can only be protected effectively by the protection of their habitats (Pócs 1992). In many tropical countries virgin forest areas have been set aside as parks or forest reserves and when well managed these protected areas may serve as refugia for rain forest species. Preliminary data on the species density of bryophyte species in a tropical rain forest (Gradstein 1992) suggest that small reserves could preserve many species, provided the “host” trees are capable of rejuvenation. The Rio Palenque Science Center in coastal Ecuador, consisting of 87 ha of mature virgin rain forest surrounded by cultivated land, may serve as an example of a small reserve with a well-developed bryophyte flora (Gradstein, personal observation).

Whether the bryophyte species will survive in these small reserves remains uncertain, however. According to Pócs (personal communication) some species are disappearing from preserved forest fragments in East Africa due to local climatic change and desiccation caused by large-scale forest destruction in the region. Also, I am not aware of the presence of any of the threatened species in these forest fragments. The relationship between habitat area and species survival thus remains unclear in bryophytes. Protection of as much as possible of the remaining natural rain forest area, as advocated by Conservation organizations such as the IUCN and the WWF, may therefore be the best approach to the conservation of the bryophyte flora.

Recommendations for future work
I would like to re-emphasize that the data and conclusions on tropical deforestation and bryophyte endangerment presented in this paper are preliminary. We need many more inventories to find out which species are locally common and which are rare. We also need more comparisons between the floras of undisturbed forest and those of secondary growth or plantations, to determine the impact of disturbance. Finally, there should be much more work on the taxonomy and habitat preferences of the rain forest taxa, to find out which species are truly endemic and
to identify those which are unable to survive in disturbed habitats. Because of the speed at which the forests are vanishing, these studies are urgent and should be undertaken today rather than tomorrow.

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