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ANDEAN MOSS DIVERSITY AND CONSERVATION: STATE OF KNOWLEDGE AND PERQUISITES FOR THE FUTURE

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RESUMEN

Los Andes tropicales contienen aproximadamente dos terceras partes de los musgos registrados para el neotrópico. El endemismo genérico se estima en un 27% y el específico entre 30-40%. Por el grado de deforestación y alteración del territorio (*ca.* 75% o más) y por su alta diversidad vegetal, los Andes tropicales merecen prioridad en los programas de conservación. El conocimiento de la biología comparada de los musgos andinos, aun en los niveles básicos de la taxonomía y geografía, es pobre. Para mejorar esta situación debe incrementarse el número de briólogos residentes y éstos deben contar con infraestructura adecuada. Los Andes tropicales representan una de las regiones de mayor diversidad vegetal en el mundo y probablemente la más rica en los trópicos (Henderson *et al.*, 1991), aun cuando los datos para el neotrópico todavía son preliminares.

Palabras clave: Colombia, Andes, musgos, diversidad, conservación.

ABSTRACT

The tropical Andes accommodate approximately two-thirds of the total moss diversity recorded for the Neotropics. Endemism for this region is estimated at 27% at the generic level and 30-40% at the species level. Given the degree of deforestation and land alteration (*ca.* 75% or more) coupled with exceedingly high plant diversity, the tropical Andes warrant a high conservation status. Present knowledge of the comparative biology of Andean mosses at the very basic levels of taxonomy and geography is at best minimal. A significant increase in the number of resident neotropical bryologists with adequate infrastructure is absolutely necessary to progress beyond our present understanding. The tropical Andes represent one of the major regions for plant diversity in the world, and likely the richest in the tropics (Henderson *et al.*, 1991). The assessment of

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regional moss diversity in the Neotropics is still in a preliminary phase, however, the tropical Andes likely contains the greatest number of species.

Key words: Colombia, Andes, mosses, diversity, conservation.

DIVERSITY

Neotropical moss diversity is estimated at 76 families, 393 genera, and about 2250 species (Churchill and Salazar Allen, unpubl. data.). The five tropical Andean countries (Venezuela, Colombia, Ecuador, Peru and Bolivia) are estimated at 75 families, 343 genera, and between 1500-1700 species (Churchill *et al.*, 1995). The tropical Andean highlands (1000 m or greater) contain an estimated 93% of the total diversity recorded for the five countries; only 7% are restricted to the lowlands of these countries. Maximum diversity for mosses is found in the transitional high montane to páramo and puna. Moss diversity recorded for the tropical Andes is approximately eight times richer than that of the much larger Amazon basin.

Problems of estimating neotropical moss diversity are that numerous species, described in the 19th Century and early 20th Century, will prove to be synonyms beyond that already known. Species figures both for the Neotropics and the tropical Andes given above represent an estimated conjecture, the actual numbers presently recognized are *ca.* 2960 for the Neotropics, and 2060 for the five Andean countries. Revisionary and floristic studies must be further advanced, particularly for many of the larger genera, before we have a firm understanding of neotropical moss diversity.

The tropical Andes contains about 60-70% of the total species diversity found in the Neotropics. The 10 largest Andean families, accounting for about 60% of the total diversity, are: Bartramiacae, Bryaceae, Callicostaceae, Dicranaceae, Fissidentaceae, Grimmiaceae, Hypnaceae, Pottiaceae, and Sematophyllaceae. Examples of speciose Andean genera include: *Bryum, Breutelia, Campylopus, Fissidens, Lepidopilum, Macromitrium, Schizmenium, Sematophyllum,* and *Sphagnum.*

Two significant patterns are evident with regard to moss diversity in the Neotropics (Churchill, 1991; Churchill *et al.*, 1995). First, a latitudinal increase in species richness from the poles to the equator, exhibited by various animal and plant groups, is approximately equivocal for mosses, and only so do to the existence of elevated highlands. Second, species richness increases with elevation, with maximum diversity encountered near the transition from high montane to páramo and puna.

ENDEMISM

The concept of endemism is defined here as taxa restricted to, or shared between, the principle phytogeographical regions within the Neotropics (*cf.* Gentry, 1982; Prance, 1989). Endemism is estimated at two families and 92 genera for the Neot-

ropics. Only the Helicophyllaceae (one genus and species) and the Hydropogoniaceae (two genera, one species each) are known to be restricted to the Neotropics. Generic endemism is relatively high, of the approximately 92 endemic genera, half are associated with two or more phytogeographical regions within the Neotropics. The remaining 46 endemic genera are restricted to the following regions: Mesoamerica 8 (Mexico 7, Central America 1), West Indies 3 (Greater Antilles), tropical Andes 25 (widespread 7, Northern Andes 5, Central Andes 13), Guayana Highlands 2, Amazon 1, and Southeast Brazil 5. There appear to be no endemic genera in the Lesser Antilles, Chocó, or Brazilian Planoalto. Generic endemism is restricted to 27 of 76 neotropical families; the 10 families with the highest number of endemic genera include: Callicostaceae 15, Pottiaceae 14, Sematophyllaceae 8, Dicranaceae 7, Brachytheciaceae 4, Ditrichaceae 4, Amblystegiaceae 3, Bryaceae 3, Hypnaceae 3, and Meteoriaceae 3.

Genera presently considered endemic to the tropical Andes (and the number of species recognized for each) include: Amblysegiaceae (*Gradsteinia* 1, *Koponenia* 1, *Richardsiopsis* 1), *Brachytheciaceae* (*Flabellidium* 1, *Mandoniella* 1,*Stenocarpidiopsis* 1), Bryaceae (*Acidodontium* 15 - two spp. extending into Central America), Callicostacee (*Callicostellopsis* 1, *Stenodesmus* 1), Dicranaceae (*Kingiobryum* 1, *Polymerodon* 1, *Pseudohyophila* 1), Grimmiaceae (*Aligrimmia* 1, *Coscinodontella* 1), Leskeaceae (*Fabronidium* 1, *Leskeadelphus 1),* Meteoriaceae *(Lindigia 1),* Pottiaceae *(Erythrophyllastrum* 1, *Erythrophyllopsis* 1, *Gertrudiella* 1, *Leptodontiella* 1, *Streptotrichum* 1, *Trachyodontium* 1), Sematophyllaceae (*Allioniellopsis* 1, *Schroeterella* 1), Thamnobryaceae (*Porotrichopsis* 1). Species endemism for the tropical Andes is presently recorded at nearly 50%, however, a more realistic estimate is 30-40% (Churchill *et al.*, 1995).

Endemism is a crucial component to phytogeography, and often used to define or support phytogeographical regions. Endemic taxa are also used to justify the protection of lands by conservationists. Pivotal to the concept of endemism, in addition to area definition, is whether or not the taxon is natural, *i.e.*, monophyletic. If a taxon is monophyletic and restricted to a geographical area, then and only then does it have potential value in discussions of phytogeography and conservation. In the Neotropics 63 of the 92 endemic genera are monotypic. What is the likelihood that these monotypic genera form a sister group with speciose genera that are morphologically variable and broader in their geographical range? With the exception of the Pottiaceae (Zander, 1993) and a few additional families, there are no phylogenetic hypotheses to support the naturalness of these genera. The following is suggested with regard to endemism (particularly to higher taxa): 1) all endemic taxa should be presumed guilty of causing paraphyly until proven innocent, and 2) the only acceptable endemic taxa are those that have been corroborated within a phylogenetic hypotheses.

ECOLOGY

Our knowledge of the ecology of Andean mosses is exceedingly limited. Much of the ecological research thus far presented is restricted to a number of vegetation studies, *i.e.*, transect or comparative site inventories. There is virtually nothing known about population structure, reproductive biology or life-history of any particular moss. This is due, in large measure, to the reciprocal lack of floras and relatively few individuals engaged in bryological research. Mosses and liverworts play a major role in maintaining the Andean ecosystem which may be as significant in many of the highlands as that recorded for the cold temperate regions. Short and long term research projects are needed to fully document the contribution bryophytes make to the Andean ecosystem.

About 30-40% of the Andean species are confined to forests, the majority as epiphytes; the remaining 60-70% are found in open montane or páramo and puna (Churchill *et al.*, 1995). Part of the explanation for the greater number of species found in open highland sites is surely a result of the continuous long and short term geological disturbances coupled with climatic effects on mountain formations. There is little doubt that the intervention of humans accelerated disturbances, and likely effected the distribution and elevational amplitude of species.

CONSERVATION

Stages in the conservation process for bryophytes, according to Söderström *et al.* (1992), involve: 1) recognizing and listing rare and decreasing species, 2) recording the distribution, biology and threats, 3) proposing conservation programs, and 4) executing these programs. The implementation of conservation practices as applied in the north temperate regions are obviously inappropriate for many tropical regions, including the tropical Andes. Reasons for this are due to the minimal level of knowledge with regard to taxonomy, distribution, and ecology of tropical mosses. Vast regions of the tropical Andes remain unexplored, particularly by trained specialists. To make any assessment of threatened or rarity of a particular moss is at best tenuous.

Present and potential threats

Present and future threats to species in the tropical highlands are similar to those of the majority of flowering plants, deforestation and land conversion for cultivation or pasture. This applies to the dry plateau highland valleys, montane forests, páramo and puna. Deforestation is not the large scale clear-cutting practiced in the lowlands, but rather at a smaller scale, by numerous, small land owners at the local level to increase pastures or cultivated lands, for fire wood, selected trees for lumber, etc. It may be possible to stop a major clear-cutting project in the Ama-

zon, but it is virtually impossible to prohibit individual families to gradually, day by day, cutting trees of a nearby forest. The basic problem, which underlies the situation, is of course, that of increasing population. This is particular true of the Andes where indigenous populations were already very well advanced before the arrival of Europeans, and exponentially accelerated to present levels.

Deforestation of the Andean montane forests is estimated at 75-90%, about the same percentage figures used to describe the remaining Amazonian forests (Henderson *et al.*, 1991). Epiphytes, including bryophytes, probably have suffered the greatest. Species extinction may have been significant, but given our state of knowledge little is known about the loss of diversity. An undeniable fact is that populations have been sharply restricted to fragmented forests. Continued deforestation will absolutely result in the extinction of many ground and epiphytic forest species unless measures are taken immediately. Montane forests may be, within a few generations, represented only by relatively few, isolated fragment islands on the Andean landscape.

Perquisites toward conservation

Among the efforts that can be taken is first to maintain what little remains of natural vegetation in the Andean ecosystem. The international bryological community can be directly involved by providing assistance toward enhancing and advancing bryology in the tropical Andes in terms of personal for teaching, providing equipment and literature through donations or purchases.

1. Support efforts toward the conservation of ecosystems or representative vegetation types as advocated for bryology or plants in general (Streimann, 1994; Wilson, 1992). This is now viewed the best approach as opposed to the protection of individual species. The compilation of threatened or rare species lists for the tropics may be useful to demonstrate that there are bryophytes facing potential extinction, but such efforts will do nothing to protect those individual species. Land conversion, including deforestation, have already progressed far beyond acceptable levels in the Andean region (75-90%). If any effort is to be made, it should be directed toward preserving all representative vegetation types, not solely forests, but also grassy or xerophytic highlands, páramos and punas. An important aspect related to highland forest conservation is the need to consider both a horizontal and vertical component with regard to zonations, and corridors between them in preserve designs (van der Hammen, 1995).

2. Provide direct support to the neotropical countries by the international bryological community and by the principle bryological societies. There are several constructive steps that can be initiated immediately to insure that we develop and increase the kind of data necessary to implement conservation practices.

Training and education. The number of active bryologists in the Neotropics are exceedingly few, and of those who are active are constrained in the amount of time they can devote to bryological research. About two-thirds of the neotropical

countries lack a bryologist; there are no professional Ph.D. bryologists in any of the Andean countries at present. An ideal goal would be to have at least one active bryologist in each country, and to assist those few institutions that do have an active bryologist. This would be a significant contribution toward our understanding of tropical bryology. Training programs or visitations for research of a few months to a year would be very beneficial. A formal degree program would provide the best means to develop the professional background to bryology. Opportunities to visit and work at an active bryological institution serves another important aspect, it connects the individual to an active international scientific community.

Workshops and courses. Where bryologists are lacking in neotropical countries and where staff and students express an interest in learning bryology, short term workshops or extended courses would provide an initial introduction. It would be ideal that such workshops or courses provide to the participants a few items such as a hand-lens, dissecting tools, slides, etc., that could be retained by them (for an investment of _50 or less per student, even if only one continues to develop an interest in bryology, the venture would be a gain for bryology).

Infrastructure assistance. There are two aspects which will determine whether an active bryological program can develop: 1) *Equipment.* Bryology does not require an expensive setup budget; basically a stereoscope and microscope. These items are often taken for granted in the Northern Hemisphere, but they are not so readily available to those in the Neotropics, or if so, then often limited to staff or students are restricted from their use. I suspect that it is this very stage that potential bryologists are lost, by simply not having access to optical equipment to commence the study of bryophytes. 2) *Literature.* One can have an active bryologist in a country, and even well-equipped, but lacking literature, individuals are equally deterred from pursuing a research program. Bryological journals and books are not present in many tropical countries, even where there is an active bryologist. Very few libraries in the Neotropics have a budget (if they have one at all) that would permit purchasing bryological literature. It may be that not all bryologists residing in temperate countries can purchase bryological journals or books, but most libraries can. Priority for providing literature should be given to institutions that have an active bryologist; it should be kept in mind, however, that the best alternative for a countries lacking a bryologist is literature. There are a few positive efforts that should be applauded that surely promote the dissemination of scientific information. The journal Tropical Bryology maintains a differential pricing between temperate subscription at a higher price, and tropical countries at a lower price. The American Bryological and Lichenological Society has recently distributed sets of The Bryologist to various Latin American institutions. Scientific books are now often published at a prohibiting price by anyone's standards, an exception to this trend is the fine series of bryological books published by the Missouri Botanical Garden; this should serve as an example to others to emulate.

3. Another high priority should be given to the preparation of florulas, synoptic treatments, and floras for the Neotropics. No single source of information can

do more to promote our understanding of tropical diversity and biology of mosses than floras. Guides and floras can summarize an enormous amount of taxonomic literature, for example, there are about 240 journal articles and books that need to be consulted for the identification of tropical Andean mosses (this number covers somewhat less than half of the Andean species). Beyond taxonomy, floras promote investigations related to all aspects of comparative biology of mosses which is implicitly lacking in the Neotropics. The only available floristic treatments are first generation, preliminary floras or keys; these include Herzog (1916) for Bolivia, Griffin (1982) for the Mérida Andes of Venezuela, Frey (1987) for portions of a transect study in Peru, and Churchill and Linares C. (1995) for Colombia.

Significant advances have been made in the last few decades in the tropical Andes and the Neotropics in general; however, the gap between our understanding of the floras of the temperate and tropical regions is still immense (Matteri, 1992). There is a world of difference between the available resources of temperate and tropical countries that are brought to bare on subjects like diversity and conservation of mosses. Consider the present bryological resources of the British Isles, for example, a bryological society with more than 350 resident members, yearly workshops and inventory surveys, a journal and bulletin, at least four generations of moss floras, and finally a three volume distribution atlas of the bryophytes. While it is doubtful that such resources will ever exist for any neotropical country, or for that matter, most countries of the world, steps can be taken to improve the situation. The most important being establishing or assisting resident bryologists in neotropical countries with adequate resources of equipment and literature.

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LITERATURE CITED

CHURCHILL, S.P. 1991.The floristic composition and elevational distribution of Colombian mosses. *Bryologist 94*: 157-167.

CHURCHILL, S.P., D. GRIFFIN, III AND M. LEWIS.1995. Moss diversity of the tropical Andes. *In*: Churchill, S.P., H. Balslev, E. Forero, J.L. Luteyn (eds.), *Biodiversity and conservation of Neotropical montane forests.* New York Botanical Garden, Bronx, pp. 335-346.

CHURCHILL, S.P. AND E.L. LINARES C. 1995. *Prodromus Bryologiae Novo-Granatensis: Introducción a la flora de musgos de Colombia.* Biblioteca José Jerónimo Triana 12, in press (2 volumes).

FREY, W. (ed.). 1987. Moosflora und -vegetation in Regenwäldern NO-Perus. *Beih. Nova Hedwigia 88*: 1-159.

GENTRY, A. 1982. Neotropical floristic diversity: Phytogeographical connections between Central America and South America, Pleistocene climatic fluctuations, or an accident of the Andean orogeny? *Ann. Missouri Bot. Gard. 69*: 557-593.

GRIFFIN, D., III. 1982. Los musgos del estado Mérida (clave para los géneros). *Pittieria 11*: 7-56.

HENDERSON, A., S.P. CHURCHILL AND J.L. LUTEYN. 1991. Neotropical plant diversity. *Nature 341*: 21-22.

HERZOG, T. 1916. Die Bryophyten meiner zweiten Reise durch Bolivia. *Biblioth. Bot. 87:* 1-347.

MATTERI, C.M. 1992. Current state of Latin American bryology. *J. Hattori Bot. Lab. 59*: 481-486.

PRANCE, G.T. 1989. American tropical forests. *In:* H. Lieth and M.J.A. Werger (eds.), *Tropical rainforest ecosystems.* Ecosystems of the world 14A. Elsevier, Amsterdam, pp. 99-132.

SÖDERSTRÖM, L., T. HALLINGBÄCK, L. GUSTAFSSON, N. CRONBERG AND L. HEDENÄS. 1992. Bryophyte conservation for the future. *Biol. Conservation 59*: 265-270.

STREIMANN, H. 1994. Conservation status of bryophytes in eastern Australia. *Trop. Bryol. 9:* 117-122.

VAN DER HAMMEN, T. 1995. Global change, biodiversity, and conservation of neotropical montane forests. *In:* S.P.Churchill, H. Balslev, E. Forero, J.L. Luteyn (eds.), *Biodiversity and conservation of Neotropical montane forests.* New York Botanical Garden, Bronx, pp. 603-607.

WILSON, E.O. 1992. *The diversity of life.* Belknap Press of Harvard University Press, Cambridge, Mass.

ZANDER, R.H. 1993. Genera of the Pottiaceae: Mosses of harsh environments. *Bull. Buffalo Soc. Nat. Sci. 32*: 1-378.