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Diversity and distribution of mosses in the state of Hidalgo, Mexico

Diversidad y distribución de musgos en el estado de Hidalgo, México

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Abstract. Through field work, bibliographic information and herbarium collections, a preliminary list of mosses for the state of Hidalgo was compiled. Records for 355 species were supported by 3 068 herbarium specimens at MEXU; when varieties are included along with taxa unsupported by local herbarium specimens, the number of taxa reaches 420. A collecting effort analysis indicates that 74.5% of the moss flora has been surveyed, that is, 56 taxa remain to be added. Species distribution modeling using 20 climatic variables from the WorldClim database for 150 species produced a map of potential distribution using a 5-minute cell network; it shows that the species potential richness is higher in central and southeastern Hidalgo, although most collections were obtained in southern and northwestern stations. Because large portions of the state land area are underexplored for mosses, no biodiversity hotspots are recognized. The Caribbean element is best represented in the Eastern Sierra Madre, but the confluence of the latter with the Neovolcanic Belt does not seem to show other major floristic differences between them, despite their geographical proximity.

Key words: richness patterns, collecting effort, potential distribution, Maxent.

Resumen. Se presenta una lista preliminar de musgos del estado de Hidalgo basada en trabajo de campo, bibliografía y colecciones de herbario. Con base en 3 068 ejemplares en MEXU se registran 355 especies, pero esta cifra se incrementa a 420 si se incluyen las variedades y los taxa sin registros en los herbarios locales. El análisis del esfuerzo de recolecta señala que se ha registrado el 74.5% de la riqueza estatal, es decir, 56 taxa menos del valor esperado. Los modelos de distribución potencial de 150 especies, usando 20 variables climáticas de la base de datos de WorldClim y una división en celdas de 5 minutos, indica que la riqueza potencial de musgos es más alta en el centro y sureste del estado, a pesar de que la mayoría de las colecciones provienen de sitios del sur y noroeste. Como partes importantes del centro del estado todavía están poco exploradas, no se reconocen zonas de alta diversidad. No se han detectado diferencias en patrones florísticos, excepto en el elemento del Caribe que está mejor representado en la sierra Madre Oriental que en el Eje Neovolcánico, a pesar de la cercanía geográfica de las 2 áreas.

Palabras clave: patrones de riqueza, esfuerzo de colecta, distribución potencial, Maxent.

Introduction

Mosses of the state of Hidalgo have been collected and studied since the beginning of the XX century. Among the early collections are those obtained by Cyrus G. Pringle through several visits to the state (Davis, 1936). His moss collections were sent to J. Cardot (1909, 1910, 1911) for identification. In mid-XX century, Crum (1951) cited specimens by various collectors, including A. J. Sharp and his collaborators, referring to them by collector name and number; most of these specimens were deposited in MICH and other American herbaria. Sharp et al. (1994) included 281 moss taxa for Hidalgo, but the Moss Flora

of Mexico did not cite specimens. In recent years, Alfaro and Castillo (1986) listed 169 species and varieties for Sierra de Pachuca; Cárdenas and Delgadillo (2009) cited specimens from localities bordering the Valley of Mexico that politically belong in Hidalgo; Delgadillo et al. (2011) listed 129 species and varieties from Los Mármoles National Park. The specimens derived from the last 3 contributions were deposited in the Bryophyte Collection at the National Herbarium (MEXU).

Despite the floristic information available, it seems that many areas in Hidalgo have not been explored for mosses, some sites are represented by many collections, and that a broader selection of sites should provide an adequate representation of the state's moss flora. Because of its geological and geographical setting, especially at the point of contact between the Eastern Sierra Madre (ESM)

and the Neovolcanic Belt (NVB), collections in the state of Hidalgo along with other nearby areas may be informative of the history of moss migration in this part of Mexico. In this contribution we offer a preliminary assessment of actual and potential species richness, and patterns of distribution; these may be in order to plan future field work in various parts of the state.

The state of Hidalgo in eastern Mexico has a surface area of nearly 21 000 km² (García and Falcón, 1984). Its rugged relief is dominated by the Eastern Sierra Madre that runs NW-SE; numerous sierras and isolated mountains are found in southern and western areas, several of them reaching more than 3 000 m in elevation (cf. INFDM, 2005). Because of its geographical position, the state is also part of the Neovolcanic Belt area.

Materials and methods

Recently collected specimens and samples deposited in MEXU were examined along with records from the literature to produce a list of moss species from the state of Hidalgo. Major literature sources of floristic and geographical information were the updated electronic version of LATMOSS 2010 (Delgadillo, 2010) and Sharp et al. (1994) that complemented specimen data. The information for 3 068 moss specimens was compiled in a georeferenced database with records for 355 species that served to calculate cell width of the area of occupancy (AOO), according to IUCN criteria (IUCN, 2001). In this

study, cell size is the longest axis between 2 collecting points divided by 10; the size of the grids (area of occupancy) was calculated by using the Conservation Assessment Tools designed for Arcview (Moat, 2007). The species cell width was averaged to obtain the width value applicable to all species; the value thus obtained, 8.4 km, was transformed to arc minutes (about 5 minutes). For further analysis, the state of Hidalgo was then divided into a network of 5-minute cells.

Collecting effort. The geographical data of the collecting records were used to produce a species accumulation curve (Gotelli and Colwell, 2001). Seventy-seven 5-minute cells with collecting records were used for the analysis. The asymptote of the accumulation curve (Fig. 1) is theoretically related to the number of species expected for the study area (Jiménez-Valverde and Hortal, 2003) and the number of cells is a measure of the collecting effort after randomly sorting these 50 times to produce a soft curve with EstimateS, version 8.2.0 (Colwell, 2009). The asymptote was estimated adjusting Clench's equation to the accumulation curve (Soberón and Llorente, 1993; Colwell and Coddington, 1994) by the Simplex and Quasi-Newton method in the STATISTICA software (StatSoft, 2011); the predicted asymptotic value was used to estimate the precision of the inventory.

Known species richness. The collecting data for 3 068 records were placed in the 5-minute cell network to identify the number of species per geographic unit and to produce a known species richness map (Fig. 2).

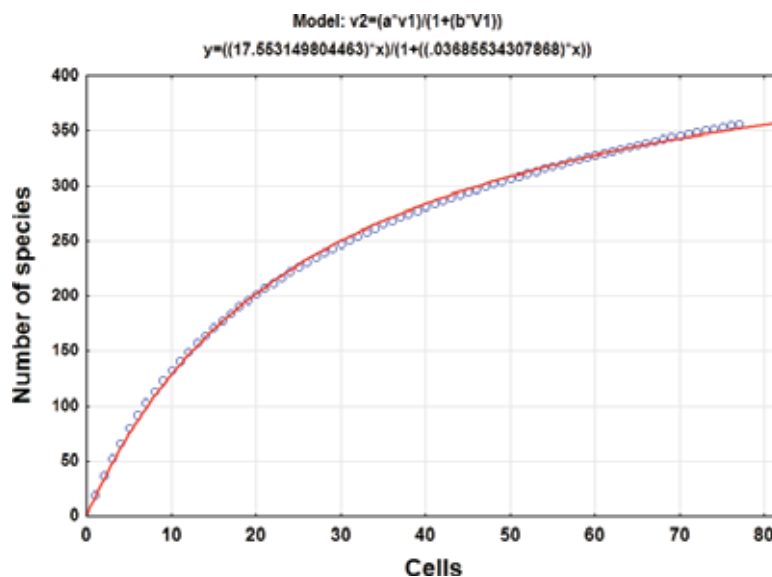


Figure 1. Accumulation curve for moss species in the state of Hidalgo. The circles represent sampling units (5 arc-minute longitude/latitude cells). Curve parameters are indicated in the equation on the upper end.

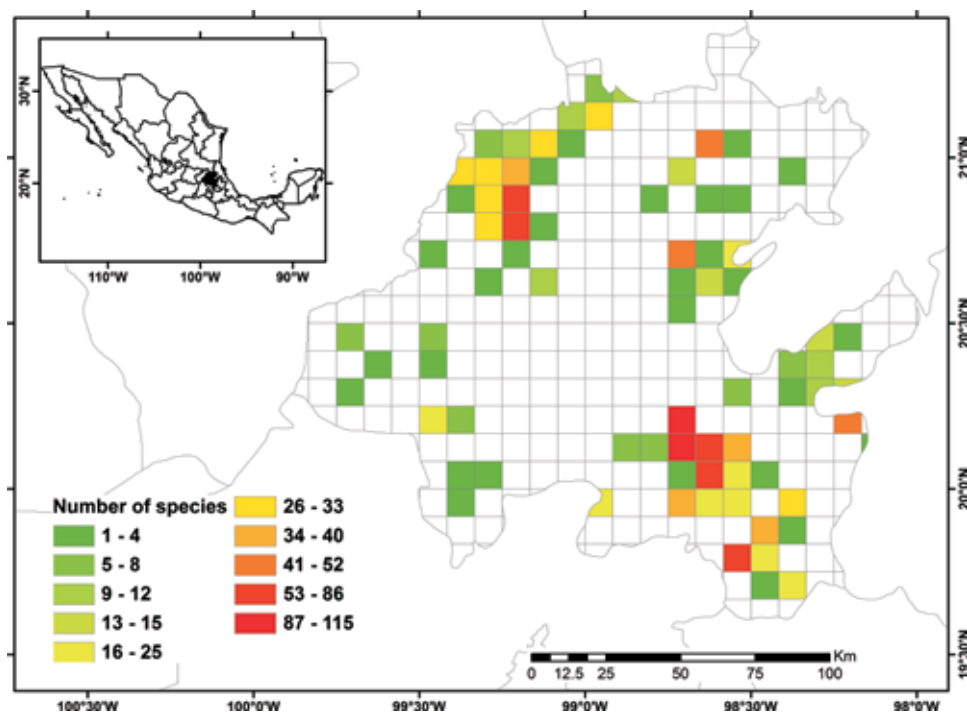


Figure 2. Known diversity is given for each 5-minute latitude/longitude cell. Readings were made at each collecting point intersection. Color scales indicate the number of species recorded.

Species distribution modeling. Twenty variables were thought to have potential predictive value for the distribution of plant species. Nineteen bioclimatic variables were obtained from the WorldClim website (Hijmans et al., 2005; <http://www.worldclim.org/bioclim.htm>) while the values of the twentieth, altitude, were obtained from an elevation digital model in the WorldClim website; spatial resolution was 1 km² for all variables.

Maxent was used to prepare models of potential distribution of 150 species (Phillips et al., 2006; Phillips and Dudik, 2008) each with at least five collecting records that were considered sufficient to obtain a reliable model. With Maxent's predetermined configuration, 75% of the records were used in model's training and the remaining 25% for the validation of the model. Models generated by Maxent show a logistic probability of 0.000 to 1.000 that may be transformed in presence-absence Boolean area maps by applying thresholds, i.e., all pixel values higher than the selected threshold are classified as "1" while a "0" value is given to the remaining pixels. The optimum threshold value has not been adequately established in Maxent (Phillips et al., 2006), however, in this contribution the threshold used was the logistic value equivalent to a 10% omission error to maintain a high proportion of correctly predicted presence records, as applied in Pearson

et al. (2007), Suarez-Seoane et al. (2008), and Kumar and Stohlgren (2009).

Potential richness. Distribution models for 150 species were placed in the 5-minute cell network to indicate the cells occupied by each species. A new richness map was produced with the models thus prepared and the records for 205 species without models supplemented the richness data for each cell. This information was used to prepare a map of potential richness (Fig. 3).

Results

Herbarium and literature records produced a list of 420 species for the state of Hidalgo (Tables 1, 2). The species accumulation curve suggests that the moss flora of the state of Hidalgo should contain about 476 species, as indicated by the asymptote (Fig. 1). Since the presence of 355 species has been documented, the level of completeness of the flora under study is 74.5%. However, computation did not consider the varieties recognized for several species so that the actual number of taxa would be 371 (Table 1). Sharp et al. (1994) recorded 49 additional taxa (Table 2) that were represented in herbarium collections elsewhere in the world and should be expected to complement holdings in MEXU. This means that there are still 56

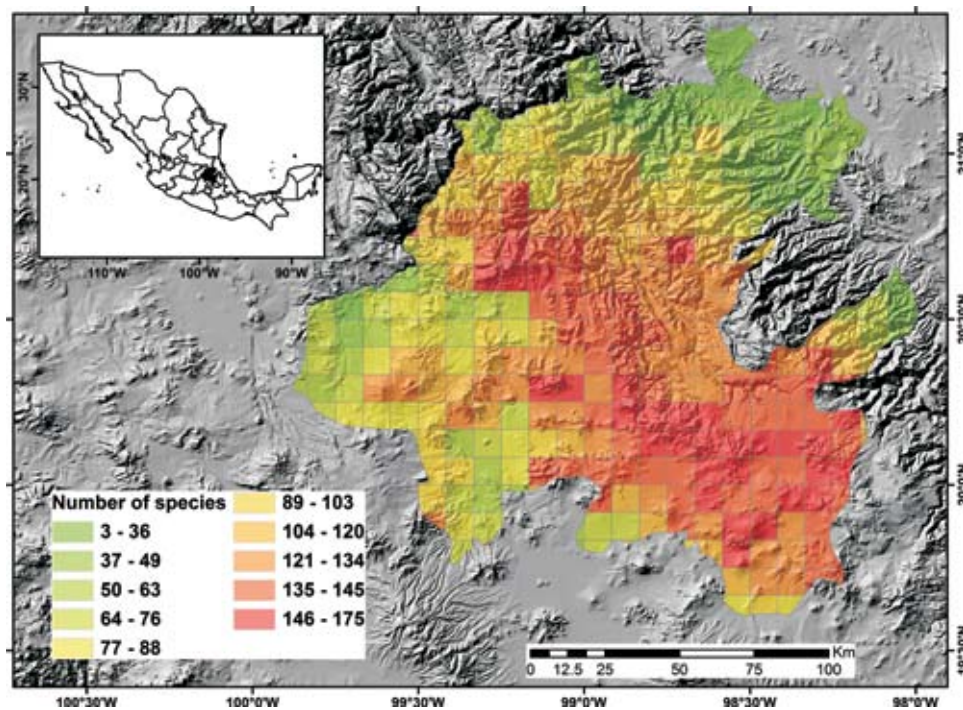


Figure 3. Patterns of richness based on potential distribution models for 150 moss species and point records for the 205 remaining species. No varieties were included. Cell size is 5-minute latitude/longitude.

Table 1. Moss taxa (371) in the state of Hidalgo, supported by herbarium specimens at MEXU. Neovolcanic Belt (NVB) and Eastern Sierra Madre (ESM) species are indicated by an X

Taxon/Element	NVB	ESM
Northern		
<i>Anomobryum filiforme</i> var. <i>concinatum</i> (Spruce) Boul.	X	
<i>Anomodon attenuatus</i> (Hedw.) Huebener	X	
<i>Anomodon rostratus</i> (Hedw.) Schimp.		X
<i>Anomodon thraustus</i> Müll. Hal.		X
<i>Atrichum angustatum</i> (Brid.) Bruch and Schimp.	X	X
<i>Barbula indica</i> (Hook.) Spreng.		X
<i>Bryum erythroloma</i> (Kindb.) Syed		X
<i>Campyliadelphus chrysophyllus</i> (Brid.) Kanda		X
<i>Campylophyllum sommerfeltii</i> (Myr.) Hedenäs	X	X
<i>Campylopus fragilis</i> (Brid.) Bruch and Schimp.	X	
<i>Ceratodon purpureus</i> subsp. <i>stenocarpus</i> (Bruch and Schimp.) Dixon	X	X
<i>Claopodium pellucinerve</i> (Mitt.) Best		X
<i>Dicranella varia</i> (Hedw.) Schimp.		X
<i>Dicranoweisia cirrata</i> (Hedw.) Lindb.	X	
<i>Dicranum flagellare</i> Hedw.	X	X
<i>Diphyscium foliosum</i> (Hedw.) Mohr	X	
<i>Drepanocladus sordidus</i> (Müll. Hal.) Hedenäs in W. R. Buck	X	
<i>Encalypta ciliata</i> Hedw.	X	
<i>Entodon schleicheri</i> (Schimp.) Demeter		X
<i>Fissidens dubius</i> P. Beauv.		X
<i>Grimmia pilifera</i> P. Beauv.	X	X
<i>Haplocladium angustifolium</i> (Hampe and Müll. Hal.) Broth.	X	X
<i>Haplocladium microphyllum</i> (Hedw.) Broth.	X	X

Table 1. Continues

Taxon/Element	NVB	ESM
<i>Heterophyllum affine</i> (Hook. ex Kunth) M. Fleisch.	X	X
<i>Hygroamblystegium fluviatile</i> (Hedw.) Loeske	X	
<i>Isopterygium tenerum</i> (Sw.) Mitt.		X
<i>Kindbergia praelonga</i> (Hedw.) Ochyra	X	
<i>Mnium marginatum</i> (With.) P. Beauv.	X	
<i>Molendoa sendtneriana</i> (Bruch and Schimp.) Limpr.		X
<i>Orthodontium gracile</i> Schwägr. ex B.S.G.	X	
<i>Oxyrrhynchium pringlei</i> (Cardot) J. T. Wynns		X
<i>Plagiomnium cuspidatum</i> (Hedw.) T. Kop.	X	
<i>Platygyrium fuscoluteum</i> Cardot	X	X
<i>Pylaisia polyantha</i> (Hedw.) Schimp.	X	X
<i>Pylaisia selwynii</i> Kindb.	X	
<i>Rhodobryum roseum</i> (Hedw.) Limpr.	X	X
<i>Rhynchostegium pulchellum</i> (Hedw.) H. Rob.	X	X
<i>Rhynchostegium riparioides</i> (Hedw.) Cardot	X	X
<i>Rhynchostegium serrulatum</i> (Hedw.) A. Jaeger	X	X
<i>Rhytidium rugosum</i> (Hedw.) Kindb.	X	X
<i>Sematophyllum marylandicum</i> (Müll. Hal.) E. Britton	X	
<i>Syntrichia fragilis</i> (Taylor) Ochyra	X	X
<i>Syntrichia ruralis</i> (Hedw.) Web. and Mohr	X	
<i>Taxiphyllum deplanatum</i> (Bruch and Schimp. ex Sull.) M. Fleisch.		X
<i>Thuidium delicatulum</i> (Hedw.) Schimp. var. <i>delicatulum</i>	X	X
<i>Thuidium delicatulum</i> var. <i>radicans</i> (Kindb.) Crum, Steere and Anders.	X	X
<i>Timmia megapolitana</i> Hedw. var. <i>bavarica</i> (Hessl.) Brid.	X	
<i>Tortella tortuosa</i> (Hedw.) Limpr.	X	X
<i>Tortula acaulon</i> (With.) R. H. Zander	X	
<i>Trichostomum crispulum</i> Bruch	X	X
<i>Trichostomum tenuirostre</i> (Hook. and Taylor) Lindb.	X	X
<i>Weissia condensa</i> (Voit) Lindb.	X	
<i>Zygodon viridissimus</i> (Dicks.) Brid.	X	
Meso-American		
<i>Aloina hamulus</i> (Müll. Hal.) Broth.	X	X
<i>Aloinella catenula</i> Cardot	X	
<i>Anomobryum plicatum</i> Cardot	X	
<i>Atractylocarpus flagellaceus</i> (Müll. Hal.) Williams	X	X
<i>Atrichum oerstedianum</i> (Müll. Hal.) Mitt.	X	X
<i>Bartramia potosica</i> Mont.	X	
<i>Brachymenium spirifolium</i> (Müll. Hal.) A. Jaeger	X	
<i>Brachythecium cirriphyloides</i> McFarland	X	X
<i>Brachythecium conostomum</i> (Taylor) A. Jaeger		X
<i>Brachythecium occidentale</i> (Hampe) A. Jaeger	X	X
<i>Braunia andrieuxii</i> Lorentz	X	
<i>Braunia squarrulosa</i> (Hampe) Müll. Hal.	X	X
<i>Bryoerythrophyllum recurvirostrum</i> (Hedw.) Chen var. <i>aeneum</i>	X	X
<i>Bryum chryseum</i> Mitt.	X	
<i>Bryum procerum</i> Schimp.	X	X
<i>Bryum richardsii</i> Sharp	X	X
<i>Campylopus anderssonii</i> (Müll. Hal.) A. Jaeger	X	X
<i>Campylopus reflexisetus</i> (Müll. Hal.) Broth.		X
<i>Catagonium brevicaudatum</i> Broth.		X
<i>Cryphaea apiculata</i> Schimp.		X
<i>Cyclodictyon erubescens</i> E. B. Bartram		X
<i>Cyclodictyon humectatum</i> Cardot		X
<i>Cyrto-hypnum mexicanum</i> (Mitt.) W. R. Buck and H. A. Crum	X	
<i>Dicranum frigidum</i> Müll. Hal.	X	X
<i>Didymodon hampei</i> R. H. Zander		X
<i>Didymodon rigidulus</i> var. <i>subulatus</i> (Thér. and E. B. Bartram) R. H. Zander	X	X

Table 1. Continues

<i>Taxon/Element</i>	<i>NVB</i>	<i>ESM</i>
<i>Entodon jamesonii</i> (Taylor) Mitt.	X	X
<i>Epipterygium immarginatum</i> Mitt.	X	
<i>Fissidens excurrentinervis</i> Williams	X	
<i>Flowersia campylopus</i> (Schimp. ex Müll. Hal.) Griffin and W. R. Buck	X	X
<i>Globulinella globifera</i> (Hampe) Steere ex Steere and Chapm.		X
<i>Herzogiella cylindricarpa</i> (Cardot) Iwats.	X	
<i>Horridohypnum mexicanum</i> (Thér.) W. R. Buck	X	X
<i>Leptodontium viticulosoides</i> (P. Beauv.) Wijk and Margad. var. <i>exasperatum</i> (Cardot) R. H. Zander	X	X
<i>Leskea angustata</i> Taylor	X	X
<i>Leucodon cryptotheca</i> Hampe	X	X
<i>Leucodon curvirostris</i> Hampe	X	X
<i>Lindbergia mexicana</i> (Besch.) Cardot	X	X
<i>Macromitrium fragilicuspis</i> Cardot		X
<i>Meteorium teres</i> Mitt.		X
<i>Mironia ehrenbergiana</i> (Müll. Hal.) R. H. Zander	X	
<i>Mironia stenotheca</i> (Thér.) R. H. Zander	X	
<i>Neckera chlorocaulis</i> Müll. Hal.	X	X
<i>Neckera ehrenbergii</i> Müll. Hal.	X	X
<i>Orthostichella pachygastrella</i> (Müll. Hal. ex Aongstr.) B. H. Allen and Magill		X
<i>Orthotrichum bartramii</i> Williams	X	
<i>Orthotrichum pycnophyllum</i> Schimp. ex Müll. Hal.	X	X
<i>Orthotrichum pycnophyllum</i> var. <i>verrucosum</i> (Müll. Hal.) Lewinsky	X	X
<i>Physcomitrium subsphaericum</i> Schimp.	X	
<i>Platygyriella pringlei</i> (Cardot) W. R. Buck		X
<i>Pohlia oerstediana</i> (Müll. Hal.) Shaw	X	
<i>Polytrichastrum tenellum</i> (Müll. Hal.) G. Smith	X	
<i>Pterobryopsis mexicana</i> (Renauld and Cardot) M. Fleisch.		X
<i>Ptychomitrium serratum</i> Bruch and Schimp.	X	X
<i>Raiuella lagoensis</i> (Hampe) W. R. Buck		X
<i>Rhexophyllum subnigrum</i> (Mitt.) Hilp.	X	X
<i>Rhynchostegium semiscabrum</i> (E. B. Bartram) H. Rob.		X
<i>Rhynchostegium subruscifforme</i> (Müll. Hal.) A. Jaeger		X
<i>Rozea andrieuxii</i> (Müll. Hal.) Besch. Var. <i>andrieuxii</i>	X	X
<i>Rozea andrieuxii</i> var. <i>bourgeana</i> (Besch.) W. R. Buck	X	X
<i>Sagenotortula quitoensis</i> (Taylor in Hook.) R. H. Zander	X	
<i>Schizymerium landii</i> (Cardot) Shaw	X	
<i>Schizymerium serratum</i> (Cardot and Herz.) Shaw	X	
<i>Sphaerotheciella pachycarpa</i> (Schimp. Ex Besch.) Manuel		X
<i>Sphaerotheciella pinnata</i> (Schimp.) Manuel	X	X
<i>Syntrichia amphidiacea</i> (Müll. Hal.) R. H. Zander	X	X
<i>Syntrichia obtusissima</i> (Müll. Hal.) R. H. Zander	X	X
<i>Thuidium delicatulum</i> var. <i>peruvianum</i> (Mitt.) H. A. Crum	X	X
<i>Zygodon ehrenbergii</i> Müll. Hal.	X	X
<i>Zygodon liebmannii</i> Schimp. Ex Müll. Hal.	X	
Caribbean		
<i>Archidium donnellii</i> Austin	X	
<i>Atrichum polycarpum</i> (Müll. Hal.) Mitt.	X	X
<i>Bartramia brevifolia</i> Brid.	X	
<i>Brachymerium mexicanum</i> Mont.	X	X
<i>Breutelia brittoniae</i> Renauld and Cardot		X
<i>Breutelia inclinata</i> (Hampe and Lorentz) A. Jaeger	X	
<i>Breutelia subarcuata</i> (Müll. Hal.) Schimp.	X	
<i>Bryum limbatum</i> Müll. Hal.		X
<i>Bryum pseudocapillare</i> Besch.	X	
<i>Campylopus albidovirens</i> Herz.	X	
<i>Campylopus tallulensis</i> Sull. and Lesq.	X	X
<i>Caribaeohypnum polypterum</i> (Mitt.) Ando and Hig.		X

Table 1. Continues

Taxon/Element	NVB	ESM
<i>Chryso-hypnum salleanum</i> (Besch.) W. R. Buck		X
<i>Cryphaea patens</i> Hornsch.	X	X
<i>Ctenidium malacodes</i> Mitt.	X	X
<i>Chryso-hypnum diminutivum</i> (Hampe) W. R. Buck		X
<i>Daltonia longifolia</i> Taylor		X
<i>Dicranum sumichrasti</i> Duby	X	X
<i>Ditrichum rufescens</i> (Hampe) Hampe		X
<i>Entodon beyrichii</i> (Schwägr.) Müll. Hal.	X	X
<i>Entodon hampeanus</i> Müll. Hal.		X
<i>Entosthodon obtusifolius</i> Hook. F. in Hook.	X	X
<i>Erythrodontium longisetum</i> (Hook.) Paris		X
<i>Fabronia ciliaris</i> var. <i>polycarpa</i> (Hook.) W. R. Buck	X	X
<i>Fabronia ciliaris</i> var. <i>wrightii</i> (Sull.) W. R. Buck	X	X
<i>Fabronia macroblepharis</i> Schwägr.	X	
<i>Fissidens crispus</i> Mont.	X	X
<i>Fissidens elegans</i> Brid.		X
<i>Fissidens polypodioides</i> Hedw.		X
<i>Holomitrium arboreum</i> Mitt.		X
<i>Homalia glabella</i> (Hedw.) Schimp.		X
<i>Hypnum amabile</i> (Mitt.) Hampe	X	X
<i>Isodrepanium lentulum</i> (Wils.) Britt.		X
<i>Leptodontium viticulosoides</i> var. <i>sulphureum</i> (Müll. Hal.) R. H. Zander	X	X
<i>Leucobryum albidum</i> (Brid. ex P. Beauv.) Lindb.	X	X
<i>Leucobryum antillarum</i> Schimp.		X
<i>Leucobryum polakowskii</i> (Müll. Hal.) Cardot		X
<i>Leucodon julaceus</i> (Hedw.) Sull.		X
<i>Leucoloma serrulatum</i> Brid.		X
<i>Macromitrium cirrosus</i> (Hedw.) Brid.	X	X
<i>Macromitrium guatemaliense</i> Müll. Hal.		X
<i>Macromitrium longifolium</i> (Hook.) Brid.	X	X
<i>Meteoridium remotifolium</i> (Müll. Hal.) Man.		X
<i>Meteorium illecebrum</i> Sull.	X	X
<i>Microcampylopus curvisetus</i> (Hampe) Giese and J.-P. Frahm		X
<i>Neckera urnigera</i> Müll. Hal.		X
<i>Papillaria deppei</i> (Hornsch. ex Müll. Hal.) A. Jaeger		X
<i>Papillaria imponderosa</i> (Taylor) Broth.		X
<i>Philonotis longiseta</i> (Mx.) E. Britton		X
<i>Philonotis sphaericarpa</i> (Hedw.) Brid.		X
<i>Phyllogonium fulgens</i> (Hedw.) Brid.		X
<i>Pilopogon guadalupensis</i> (Brid.) J.-P. Frahm		X
<i>Pilotrichella mauiensis</i> (Sull.) A. Jaeger		X
<i>Pirella pohlii</i> (Schwägr.) Cardot		X
<i>Plagiothecium drepanophyllum</i> Renauld and Cardot	X	
<i>Pleuroidium mexicanum</i> Cardot	X	
<i>Pogonatum campylocarpum</i> (Müll. Hal.) Mitt.	X	X
<i>Pogonatum tortile</i> (Sw.) Brid.		X
<i>Pohlia richardsii</i> Shaw	X	
<i>Porotrichum korthalsianum</i> (Dozy and Molke.) Mitt.	X	X
<i>Porotrichum longirostre</i> (Hook.) Mitt.	X	X
<i>Porotrichum mutabile</i> Hampe		X
<i>Pseudosymblepharis schimperiana</i> (Paris) H. A. Crum	X	X
<i>Pterobryon densum</i> Hornsch.	X	X
<i>Ptychomitrium lepidomitrium</i> (Müll. Hal.) Schimp. in Besch.	X	X
<i>Rhodobryum beyrichianum</i> (Hornsch.) Müll. Hal. ex Hampe	X	X
<i>Rhynchostegiopsis flexuosa</i> (Sull.) Müll. Hal.		X
<i>Rhynchostegium scariosum</i> (Taylor) A. Jaeger		X
<i>Rigodium toxarton</i> (Schwägr.) A. Jaeger		X

Table 1. Continues

<i>Taxon/Element</i>	<i>NVB</i>	<i>ESM</i>
<i>Schlotheimia jamesonii</i> (Arnott) Brid.		X
<i>Schlotheimia rugifolia</i> (Hook.) Schwägr.		X
<i>Sematophyllum cuspidiferum</i> Mitt.		X
<i>Sematophyllum swartzii</i> (Schwägr.) Welch and H. A. Crum	X	X
<i>Sphagnum meridense</i> (Hampe) Müll. Hal.		X
<i>Splachnobryum obtusum</i> (Brid.) Müll. Hal.		X
<i>Squamidium nigricans</i> (Hook.) Broth.		X
<i>Syrrhopodon prolifer</i> Schwägr.		X
<i>Thuidium tomentosum</i> Schimp.	X	X
<i>Weissia jamaicensis</i> (Mitt.) Grout		X
<i>Zelometeorium patulum</i> (Hedw.) Manuel		X
<i>Zygodon campylophyllus</i> Müll. Hal.	X	X
Southern		
<i>Braunia plicata</i> (Mitt.) A. Jaeg.	X	X
<i>Bryum microimbricatum</i> Ochi	X	
<i>Bryum radiculosum</i> Brid.		X
<i>Campylopus heterostachys</i> (Hampe) A. Jaeger		X
<i>Erpodium beccarii</i> Müll. Hal. ex Vent.		X
<i>Leptodontium capituligerum</i> Müll. Hal.	X	X
<i>Orthotrichum aequatoreum</i> Mitt.	X	X
<i>Rhacocarpus purpurascens</i> (Brid.) Paris		X
Wide distribution		
<i>Aloina rigida</i> (Hedw.) Limpr.		X
<i>Amphidium tortuosum</i> (Hornsch.) Cufodontis	X	
<i>Anacolia laevisphaera</i> (Taylor) Flowers	X	X
<i>Andreaea rupestris</i> Hedw.	X	
<i>Anoetangium aestivum</i> (Hedw.) Mitt.	X	X
<i>Anomobryum filiforme</i> (Dicks.) Solms. in Rabenh. var. <i>filiforme</i>	X	
<i>Anomodon tristis</i> (Ces.) Sull. and Lesq.		X
<i>Aongstroemia orientalis</i> Mitt.	X	X
<i>Barbella pendula</i> (Sull.) M. Fleisch.		X
<i>Barbellopsis trichophora</i> (Mont.) W. R. Buck		X
<i>Barbula arcuata</i> Griff.		X
<i>Barbula bolleana</i> (Müll. Hal.) Broth.	X	X
<i>Barbula convoluta</i> Hedw.		X
<i>Brachymenium exile</i> (Dozy and Molk.) Bosch and Sande Lac.	X	X
<i>Brachymenium systylium</i> (Müll. Hal.) A. Jaeger	X	X
<i>Brachymitrium jamesonii</i> Taylor	X	X
<i>Brachythecium plumosum</i> (Hedw.) Schimp.	X	X
<i>Brachythecium ruderale</i> (Brid.) W. R. Buck	X	X
<i>Braunia secunda</i> (Hook.) Bruch and Schimp.	X	X
<i>Breutelia tomentosa</i> (Brid.) A. Jaeg. and Sauerb.		X
<i>Bryoerythrophyllum campylocarpum</i> (Müll. Hal.) H. A. Crum	X	X
<i>Bryoerythrophyllum inaequalifolium</i> (Taylor) R. H. Zander	X	
<i>Bryoerythrophyllum recurvirostrum</i> var. <i>recurvirostrum</i>	X	
<i>Bryum argenteum</i> Hedw.	X	X
<i>Bryum billarderi</i> Schwägr.	X	X
<i>Bryum capillare</i> Hedw.	X	X
<i>Bryum muhlenbeckii</i> Bruch and Schimp.	X	
<i>Bryum pallescens</i> Schleich. ex Schwägr.		X
<i>Bryum pseudotriquetrum</i> (Hedw.) Gaertn., Meyer and Scherb.	X	
<i>Bryum subapiculatum</i> Hampe	X	
<i>Campylopus flexuosus</i> (Hedw.) Brid.		X
<i>Campylopus nivalis</i> (Brid.) Brid.	X	X
<i>Campylopus pilifer</i> Brid.	X	X
<i>Campylopus savannarum</i> (Müll. Hal.) Mitt.		X

Table 1. Continues

Taxon/Element	NVB	ESM
<i>Campylopus sinensis</i> (Müll. Hal.) J.-P. Frahm	X	
<i>Ceratodon purpureus</i> (Hedw.) Brid. subsp. <i>purpureus</i>	X	X
<i>Crossidium crassinervium</i> (De Not.) Jur.		X
<i>Cryphaea jamesonii</i> Taylor		X
<i>Cyrto-hypnum minutulum</i> (Hedw.) W. R. Buck and H. A. Crum		X
<i>Desmatodon convolutus</i> (Brid.) Grout	X	X
<i>Didymodon australasiae</i> (Hook. and Grev.) R. H. Zander	X	X
<i>Didymodon ferrugineus</i> (Schimp. ex Besch.) M.O. Hill		X
<i>Didymodon revolutus</i> (Cardot) Williams	X	X
<i>Didymodon rigidulus</i> Hedw. var. <i>gracilis</i> (Schleich. ex Hook. and Grev.) R. H. Zander	X	X
<i>Didymodon rigidulus</i> var. <i>icmadophilus</i> (Schimp. ex Müll. Hal.) R. H. Zander	X	X
<i>Didymodon rigidulus</i> var. <i>rigidulus</i>	X	X
<i>Didymodon vinealis</i> (Brid.) R. H. Zander		X
<i>Distichium capillaceum</i> (Hedw.) Bruch and Schimp.	X	
<i>Drepanocladus aduncus</i> (Hedw.) Warnst.		X
<i>Entodon macropodus</i> (Hedw.) Müll. Hal.		X
<i>Entosthodon muhlenbergii</i> (Turner) Fife	X	
<i>Eustichia longirostris</i> (Brid.) Brid.		X
<i>Fabronia ciliaris</i> (Brid.) Brid. var. <i>ciliaris</i>	X	X
<i>Fissidens asplenioides</i> Hedw.	X	X
<i>Fissidens curvatus</i> Hornsch.	X	
<i>Fissidens pellucidus</i> Hornsch.		X
<i>Fissidens submarginatus</i> Bruch in Krauss		X
<i>Fissidens taxifolius</i> Hedw.		X
<i>Fissidens weirii</i> Mitt. var. <i>hemicraspedophyllus</i> (Cardot) Pursell		X
<i>Forsstroemia producta</i> (Hornsch.) Paris	X	X
<i>Forsstroemia trichomitria</i> (Hedw.) Lindb.		X
<i>Funaria hygrometrica</i> Hedw. var. <i>calvescens</i> (Schwägr.) Mont.	X	X
<i>Funaria hygrometrica</i> var. <i>hygrometrica</i>	X	X
<i>Grimmia longirostris</i> Hook.	X	
<i>Grimmia ovalis</i> (Hedw.) Lindb.	X	
<i>Grimmia trichophylla</i> Grev.	X	
<i>Groutiella tomentosa</i> (Hornsch.) Wijk and Margad.		X
<i>Gymnostomum aeruginosum</i> Sm.	X	X
<i>Hedwigia ciliata</i> (Hedw.) P. Beauv.	X	X
<i>Hedwigidium integrifolium</i> (P. Beauv.) Dixon	X	
<i>Henicodium geniculatum</i> (Mitt.) W. R. Buck		X
<i>Herpetineuron toccoe</i> (Sull. and Lesq.) Cardot		X
<i>Homaliodendron flabellatum</i> (Sm.) M. Fleisch.		X
<i>Hookeria acutifolia</i> Hook. and Grev.		X
<i>Hymenostylium recurvirostrum</i> (Hedw.) Dixon		X
<i>Hyophila involuta</i> (Hook.) A. Jaeger	X	X
<i>Hypnum cupressiforme</i> Hedw. var. <i>cupressiforme</i>	X	X
<i>Hypnum cupressiforme</i> var. <i>lacunosum</i> Brid.	X	X
<i>Hypnum revolutum</i> (Mitt.) Lindb.	X	
<i>Hypopterygium tamarisci</i> (Sw.) Brid. ex Müll. Hal.		X
<i>Leptobryum pyriforme</i> (Hedw.) Wilson		X
<i>Leptodictyum riparium</i> (Hedw.) Warnst.		X
<i>Leptodontium brachyphyllum</i> Broth. and Thér.	X	
<i>Leptodontium flexifolium</i> (Dicks. ex With.) Hampe	X	X
<i>Leptodontium viticulosoides</i> var. <i>viticulosoides</i>	X	X
<i>Leptohymenium tenue</i> (Hook.) Schwägr.		X
<i>Lescuraea arizonae</i> (R.S. Williams) P.S. Wilson and D.H. Norris	X	X
<i>Macrocoma orthotrichoides</i> (Raddi) Wijk and Margad.	X	X
<i>Macrocoma tenuis</i> (Hook. and Grev.) Vitt subsp. <i>sullivantii</i>	X	X
<i>Microbryum starkeanum</i> (Hedw.) R. H. Zander	X	
<i>Mittenothamnium reptans</i> (Hedw.) Cardot	X	X

Table 1. Continues

<i>Taxon/Element</i>	<i>NVB</i>	<i>ESM</i>
<i>Orthostichella rigida</i> (Müll. Hal.) B. H. Allen and Magill	X	X
<i>Orthostichella versicolor</i> (Müll. Hal.) B. H. Allen and Magill		X
<i>Orthotrichum anomalum</i> Hedw.		X
<i>Orthotrichum diaphanum</i> Schrad. ex Brid.	X	
<i>Palamocladium leskeoides</i> (Hook.) E. Britton	X	X
<i>Papillaria nigrescens</i> (Sw. ex Hedw.) A. Jaeger	X	X
<i>Philonotis fontana</i> (Hedw.) Brid.	X	
<i>Philonotis glaucescens</i> (Hornsch.) Broth.		X
<i>Philonotis marchica</i> (Hedw.) Brid.		X
<i>Pilotrichella flexilis</i> (Hedw.) Aongstr.	X	X
<i>Plagiomnium rhynchophorum</i> (Hook.) T. Kop.	X	X
<i>Platygyriella densa</i> (Hook.) W. R. Buck	X	
<i>Pleuridium acuminatum</i> Lindb.	X	
<i>Pleurochaete squarrosa</i> (Brid.) Lindb.	X	X
<i>Pogonatum oligodus</i> (Müll. Hal.) Mitt.	X	
<i>Pohlia cruda</i> (Hedw.) Lindb.	X	
<i>Pohlia elongata</i> Hedw.	X	X
<i>Polytrichum commune</i> L. ex Hedw.		X
<i>Polytrichum juniperinum</i> Hedw.	X	X
<i>Porotrichum usagarum</i> Mitt.	X	
<i>Prionodon densus</i> (Hedw.) Müll. Hal.	X	X
<i>Pseudocrossidium crinitum</i> (Schultz) R. H. Zander	X	
<i>Pseudocrossidium replicatum</i> (Taylor) R. H. Zander	X	X
<i>Pylaisia falcata</i> Schimp.	X	X
<i>Pylaisiadelphina tenuirostris</i> (Bruch and Schimp.) W. R. Buck	X	X
<i>Pyrrhobryum spiniforme</i> (Hedw.) Mitt.		X
<i>Racomitrium subsecundum</i> (Hook. and Grev. ex Harv.) Mitt.	X	
<i>Racopilum tomentosum</i> (Hedw.) Brid.	X	X
<i>Rhabdoweisia fugax</i> (Hedw.) Bruch and Schimp.	X	X
<i>Rhodobryum huillense</i> (Welw. and Duby) Touw	X	X
<i>Schistidium apocarpum</i> (Hedw.) Bruch and Schimp.	X	
<i>Schistidium rivulare</i> (Brid.) Podp.	X	
<i>Sematophyllum adnatum</i> (Mx.) E. Britton	X	X
<i>Sematophyllum galipense</i> (Müll. Hal.) Mitt.	X	X
<i>Sematophyllum subpinnatum</i> (Brid.) E. Britton	X	X
<i>Sematophyllum subsimplex</i> (Hedw.) Mitt.		X
<i>Sphagnum palustre</i> L.	X	X
<i>Sphagnum strictum</i> Sull.		X
<i>Stereophyllum radiculosum</i> (Hook.) Mitt.		X
<i>Symblepharis vaginata</i> (Hook.) Wijk and Margad.	X	
<i>Syntrichia chisosa</i> (Magill, Delgad. and L. R. Stark) R. H. Zander	X	
<i>Syntrichia pagorum</i> (Milde) Amann	X	
<i>Syntrichia papillosa</i> (Wilson) Jur.	X	
<i>Taxiphyllum taxirameum</i> (Mitt.) M. Fleisch.		X
<i>Timmia anomala</i> (Bruch and Schimp.) Limpr.	X	X
<i>Tortella humilis</i> (Hedw.) Jenn.		X
<i>Trachypus viridulus</i> (Mitt.) Broth.		X
<i>Trematodon</i> sp.	X	
<i>Trichostomum brachydontium</i> Bruch	X	X
<i>Weissia controversa</i> Hedw.	X	X
<i>Zygodon obtusifolius</i> Hook.	X	X
<i>Zygodon reinwardtii</i> (Hornsch.) Braun	X	
Endemic		
<i>Brachymenium saint-pierrei</i> Thér.	X	
<i>Didymodon incrassatolimbatus</i> Cardot	X	
<i>Entodon abbreviatus</i> (Schimp.) A. Jaeger	X	X
<i>Grimmia involucreta</i> Cardot	X	

Table 1. Continues

<i>Taxon/Element</i>	<i>NVB</i>	<i>ESM</i>
<i>Grimmia pulla</i> Cardot	X	
<i>Hennediella heteroloma</i> (Cardot) R. H. Zander var. <i>eckeliae</i> R. H. Zander		X
<i>Homomallium sharpii</i> Ando and Higuchi		X
<i>Jaffuelobryum arsenei</i> (Thér.) Thér.	X	
<i>Neckera angustifolia</i> Müll. Hal.		X
<i>Oreoweisia delgadilloi</i> H. Rob. and F. D. Bowers	X	X
<i>Pylaisiadelphu duellii</i> H. A. Crum	X	
<i>Synthodontium pringlei</i> Cardot	X	
<i>Weissia semidiaphana</i> (Thér.) R. H. Zander	X	
Chihuahuan		
<i>Entosthodon apiculatopilosus</i> (Cardot) Fife	X	
<i>Homomallium mexicanum</i> Cardot	X	X
<i>Weissia ligulifolia</i> (E. B. Bartram) R. H. Zander	X	

taxa lacking to fulfill the model prediction. The 420 moss taxa known from the state (Tables 1, 2) represent a high floristic number for the area. To be sure, published data indicate that such neighboring states as Guanajuato harbor 114 moss species and varieties (Delgadillo and Cárdenas, 1996), México 268 (Sharp et al., 1994), and Querétaro 212 (Herrera et al., 2008); it seems that a higher number may be found once the central dry lands and other forested areas are explored.

The list of species based on herbarium specimens (Table 1) also cites the taxa represented in the major mountain systems of the state, i.e., the Neovolcanic Belt with 245 taxa, and the Eastern Sierra Madre with 275. There are no strong differences in the number of taxa between mountain systems, but the Caribbean taxa are distinctly higher in the ESM (Table 3). Besides this, salient features of the moss flora include the large group of widely distributed and the Meso-American taxa. The endemic species, 12 in total, are not restricted to Hidalgo or to a topographic feature of the state and represent less than 3% of the entire moss flora. Because of their small number, it is also remarkable the presence of members of the Chihuahuan element.

The species listed in table 2 may follow the same patterns of distribution as those listed in table 1, but should be added when their state distribution is confirmed.

Figure 2 shows the number of known species per cell in the state of Hidalgo. The distribution of cells with data also indicate the extent of field work thus far conducted; there are numerous collections from SE and NW areas, followed in order of importance, by the NE and SW areas. These were obtained along major highways and forested areas along the way. The empty cells in the map represent dry lands or scattered peaks, inaccessible areas, and major cities and industrial areas. The potential distribution map for 150 species (Fig. 3) suggests that many of the empty cells in figure 2 may contain rich moss floras, especially

in central and southeastern parts of the state. However, potential species richness values become smaller toward the northeastern lowlands and, in the southwest, toward the lower areas of the Neovolcanic Belt.

Discussion

The known moss flora of the state of Hidalgo is comparatively larger than that of adjacent states. Part of the size differences are undoubtedly due to insufficient bryological exploration in various states in central Mexico. The dry continental area north of the NVB and to the west of the ESM may indeed contain a reduced moss flora, but full diversity evaluations in Hidalgo require ample exploration in its central region. The size of the moss flora, with 420 species and varieties, is potentially more diverse as suggested in preceding paragraphs, but not as rich as that of Veracruz which includes more than 500 taxa (Delgadillo, 2011).

The presence of 2, NVB and ESM, groups of species of presumed different derivation might suggest a state flora with higher moss diversity or with peculiar geographical affiliation in the mountain areas. Neither hypothesis is confirmed by the results summarized in table 3; except for the values of the Caribbean element, the number of species in the NVB and in ESM is similar, perhaps due to the close proximity of the mountain ranges. The Caribbean species are an important constituent of the tropical floras of Mexico and these, along with the Meso-American and endemic taxa give a neotropical character to the flora of Hidalgo.

With respect to diversity, the number of species in Hidalgo is higher than in neighboring states, but no hotspots are readily identified with current data, although there are areas (e.g., between Zimapán and Jacala in the northwest, and in Sierra de Pachuca) where actual or potential species richness is higher (Figs. 2, 3). These areas, however, have

Table 2. Moss taxa listed in Sharp et al. (1994), not supported by specimens at MEXU. Endemic taxa are indicated by “+”

<i>Taxon</i>
<i>Acroporium longirostre</i> (Brid.) W. R. Buck
<i>Aerobryopsis martinicensis</i> (Broth.) Spessard-Schued.
<i>Anomobryum prostratum</i> (Müll.Hal.) Besch.
<i>Aulacomnium palustre</i> (Hedw.) Schwägr.
<i>Barbula orizabensis</i> Müll.Hal.
<i>Brachymenium radiculosum</i> (Schwägr.) Hampe
<i>Breutelia austroarcuata</i> (Müll. Hal.) Paris
<i>Breutelia jamaicensis</i> (Mitt.) A. Jaeger
<i>Bryoerythrophyllum recurvirostrum</i> (Hedw.) Chen var. <i>aeneum</i> (Müll. Hal.) R. H. Zander
<i>Bryum apiculatum</i> Schwägr.
<i>Bryum caespiticium</i> Hedw.
<i>Bryum leptotorquescens</i> Müll.Hal.ex Broth.
<i>Bryum microchaeton</i> Hampe
<i>Calyptothecium duplicatum</i> (Schwägr.) Broth.
<i>Chryso-hypnum salleanum</i> (Besch.) W. R. Buck
<i>Cryphaea filiformis</i> (Hedw.) Brid.
<i>Cyclodictyon albicans</i> (Hedw.) Kuntze
<i>Daltonia tenuifolia</i> Mitt.
+ <i>Dicranella barnesii</i> Cardot
<i>Dicranella hilariana</i> (Mont.) Mitt.
<i>Dicranella lindigiana</i> (Hampe) Mitt.
+ <i>Dicranum lophoneuron</i> Müll. Hal.
<i>Didymodon tophaceus</i> (Brid.) Lisa
<i>Didymodon umbrosus</i> (Müll. Hal.) R. H. Zander
<i>Entodon serrulatus</i> Mitt.
<i>Entosthodon bonplandii</i> (Hook.) Mitt.
<i>Epipterygium mexicanum</i> (Besch.) Broth.
<i>Fissidens weirii</i> Mitt.var. <i>weirii</i>
<i>Grimmia elongata</i> Kaulf.
<i>Helicodontium capillare</i> (Hedw.) A. Jaeger
<i>Heterocladium macounii</i> Best
<i>Hyophiladelphus agrarius</i> (Hedw.) R. H. Zander
<i>Luisierella barbula</i> (Schwägr.) Steere
<i>Macromitrium punctatum</i> (Hook.and Grev.) Brid.
<i>Neckeropsis undulata</i> (Hedw.) Reichardt
<i>Philonotis cernua</i> (Wilson) Griffin and W. R. Buck
<i>Philonotis uncinata</i> (Schwägr.) Brid.
<i>Pilotrichella nudiramulosa</i> Müll.Hal.
<i>Plaubelia sprengelii</i> (Schwägr.) R. H. Zander var. <i>stomatodonta</i> (Cardot) R. H. Zander
<i>Pohlia papillosa</i> (Müll. Hal. ex Jaeger) Broth.
<i>Pohlia pseudobarbula</i> (Thér.) H. A. Crum ex A. J. Shaw
<i>Porotrichodendron lindigii</i> (Hampe) W. R. Buck
<i>Pylaisiadelpha deplanatula</i> (Cardot) W. R. Buck
<i>Rhachithecium perpusillum</i> (Thwaites and Mitt.) Broth.
<i>Schoenobryum concavifolium</i> (Griff.) Gangulee
<i>Streptopogon cavifolius</i> Mitt.
<i>Streptopogon matudianus</i> H. A. Crum
<i>Syntrichia bogotensis</i> (Hampe) Mitt.
<i>Trachypodopsis serrulata</i> (P. Beauv.) M. Fleisch. var. <i>crispatula</i> (Hook.) Zant.

Table 3. Summary of number of species listed in Table 1. NVB= Neovolcanic Belt; ESM= Eastern Sierra Madre

<i>Element</i>	<i>NVB</i>	<i>ESM</i>	<i>Total</i>
Northern	40	34	53
Meso-American	53	50	70
Caribbean	37	71	81
Southern	4	7	8
Wide distribution	98	107	143
Endemic	10	5	13
Chihuahuan	3	1	3
Total	245	275	371

been well collected and may not qualify for designation as hotspots.

The potential distribution map identifies areas of concentration of species; because of the habitat interrelationships between mosses and vascular plants, the map in figure 3 would be similar to the distribution of certain vascular plant communities. At present, it is unknown whether their distribution is comparable, but if field observations confirm this, mosses would be an additional criterion to justify conservation of diverse areas.

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