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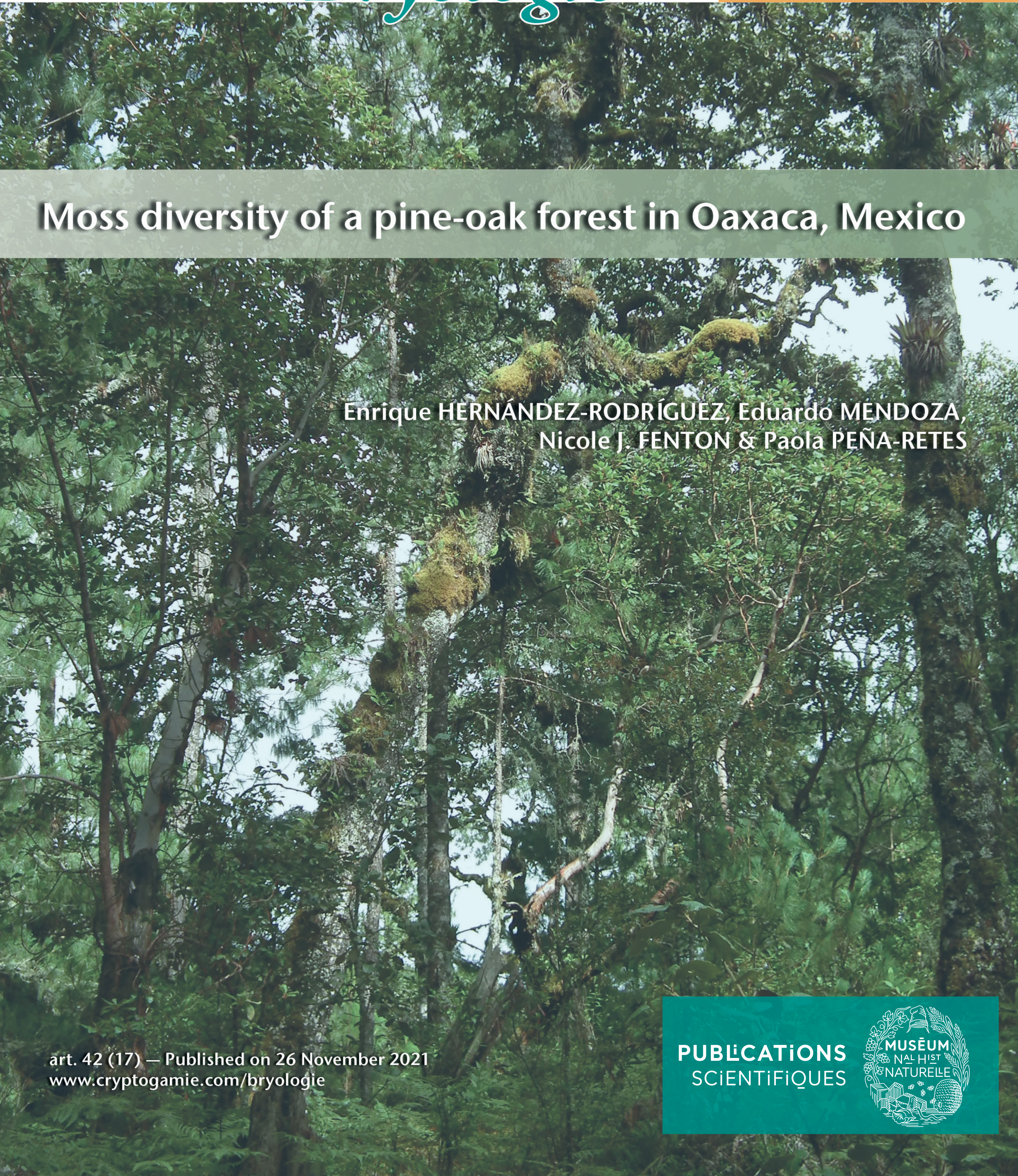

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Moss diversity of a pine-oak forest in Oaxaca, Mexico

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ABSTRACT
The pine-oak forests of Mexico are reservoirs of high biological diversity, largely due to their high richness of vascular flora. However, mosses have received little attention. We studied the floristic composition, diversity, and species richness of the moss community in the pine-oak forests of the Sierra Norte of Oaxaca, Mexico. A comprehensive list of the species occurring in the region was made by reviewing herbarium databases and conducting fieldwork. We analyzed alpha and beta diversity, as well as community structure, based on 60 sampling sites. Our results show the occurrence of 339 species of mosses in the study area, distributed in 168 genera and 52 families. We found high α and β diversity values compared with other vegetation types in Mexico. Our study provides a more detailed portrait of the high moss diversity occurring in the region.

KEY WORDS
Alpha diversity,
beta diversity,
epiphytic bryophytes,
terrestrial bryophytes,
temperate forests,
Quercus,
Mexico flora.

RÉSUMÉ
Diversité des mousses d'une forêt de pins et de chênes à Oaxaca, Mexique.
Les forêts de pins et de chênes du Mexique sont des réservoirs d'une importante diversité biologique, en grande partie en raison de leur richesse en flore vasculaire. Cependant, les mousses ont reçu peu d'attention. Nous avons étudié la composition floristique, la diversité et la richesse en espèces de la

MOTS CLÉS
Diversité alpha, diversité bêta, bryophytes épiphytes, bryophytes terrestres, forêts tempérées, *Quercus*, flore mexicaine.

communauté de mousses dans les forêts de pins et de chênes de la Sierra Norte d'Oaxaca, au Mexique. Une liste complète des espèces présentes dans la région a été établie en examinant les bases de données d'herbier et en menant des travaux sur le terrain. Nous avons analysé la diversité alpha et bêta, ainsi que la structure de la communauté, sur la base de 60 sites d'échantillonnage. Nos résultats montrent la présence de 339 espèces de mousses dans la zone d'étude, réparties en 168 genres et 52 familles. Nous avons trouvé des valeurs de diversité α et β élevées par rapport à d'autres types de végétation au Mexique. Notre étude fournit une perspective plus détaillée de la grande diversité des mousses présentes dans la région.

INTRODUCTION

Pine-oak forests constitute one of the most notable plant associations occurring in Mexico due to its extent (*c.* 88, 220 km^2) and level of endemism (Miranda & Hernández 1963; Boege 2008). These forests support an estimated 7000 vascular plant species, contributing to make Mexico a megadiverse country (Rzedowski 1991). Pine-oak forests have a broad distribution in Mexico, including the physiographic regions of the Sierra Madre Occidental, the Sierra Madre Oriental, the Trans-Mexican Volcanic Belt, and the Sierra Madre del Sur. The Sierra Madre del Sur includes the political region of Sierra Norte in the state of Oaxaca, which has been identified as a habitat for a large number of bird species (Benitez *et al.* 1999) and as one of the most important centers of vascular plant endemism in the country (Mittermeier *et al.* 2004; Suárez-Mota *et al.* 2018; Enquist *et al.* 2019).

Moreover, pine-oak forests are of great importance due to the fact they provide different ecosystem services, such as material for industry (e.g. 76% of the country's timber production comes from these forests; De Jong *et al.* 2007), regulation of environmental processes like carbon sequestration (Laguna *et al.* 2009; Pompa-Garcia & Sigala Rodríguez 2017), and recreational, educational and cultural services to local communities (Miranda & Hernández 1963; Galicia & Zarco-Arista 2014). In spite of this, our knowledge about the global magnitude of the diversity forests in this region harbors is incomplete due to the fact that information for several taxa is missing.

Mosses play essential ecological roles in pine-oak forests. For example, terrestrial mosses are among the most favorable germination substrates for some of the vascular plants occurring in this type of ecosystem (García-Ávila 1998), and they represent natural pollen reservoirs of up to 40 taxa (Domínguez-Vázquez *et al.* 2004; Chang-Martínez & Domínguez-Vázquez 2013). Moreover, epiphytic mosses provide support and contribute to the establishment of orchids and bromeliads (Hernández-Pérez *et al.* 2018). Both terrestrial mosses and epiphytes are part of the forest biomass and play roles in the water balance and the nutrient cycle in these ecosystems (Proctor 2009: Ah-Peng *et al.* 2017). Finally, mosses are culturally important as local communities use some of them for different activities (Hernández-Rodríguez & Delgadillo 2021).

Oaxaca is the state with the second-highest moss richness in Mexico (Delgadillo 2014; Ellis *et al.* 2021), which is likely related to the existence of significant variation in moss diversity among vegetation types occurring in the region (Delgadillo & Zander 1984; Rivera-Aguilar *et al.* 2006; Hernández-Rodríguez & Aguirre Hidalgo 2020). There are some floristic checklists for the vascular flora of the Sierra Norte of Oaxaca (Torres-Colín *et al.* 2009; Suárez-Mota *et al.* 2018) but, no consensus exists regarding the magnitude of moss richness occurring in temperate forest in the region. A better knowledge of the diversity of mosses in the region is urgent due to increasing threats associated with wildfires (González-Tagle *et al.* 2008), habitat fragmentation (Asbjornsen *et al.* 2004), use of inappropriate forestry methods (Sánchez-González 2008) and, overall, land-use changes (Gómez-Mendoza *et al.* 2006).

In this study, we address a set of important questions aimed at gaining a better understanding of the diversity of mosses in this region: a) How many moss species can be found in this region's temperate pine-oak forests? b) How does species richness and composition (α and β diversity) vary among different sampling localities? c) Which are the most common and rarest species? We address these questions by distinguishing between mosses living on the ground (terrestrial) and those living on trees (epiphytes).

MATERIAL AND METHODS

Study area

The Sierra Norte of Oaxaca is located in southern Mexico (16°58' and 17°48' latitude N and 95°8' and 96°47' longitude W; Fig. 1). This region is divided into three political-administrative districts, Ixtlán (or Sierra Juárez), Mixe, and Villa Alta (Suárez-Mota *et al.* 2018), which support cloud forests, tropical evergreen, deciduous forests, and pine-oak forests (Rzedowski 1978; Torres-Colín 2004). Pine-oak forests occur in an altitudinal range from 2000 to 2 800 m and include species such as *Pinus rudis* Endl., *P. devoniana* Endl., *P. lawsonii* Roezl ex Gordon, *P. montezumae* Lamb., *Quercus laurina* Bonpl., and *Q. rugosa* Née (Dávila *et al.* 1997). In these forests, indigenous communities have developed sustainable economic activities over the last decades, including forest management and ecotourism (Leopold 1950; Chapela 2005; Pazos-Almada & Bray 2018). The main causes of dis-

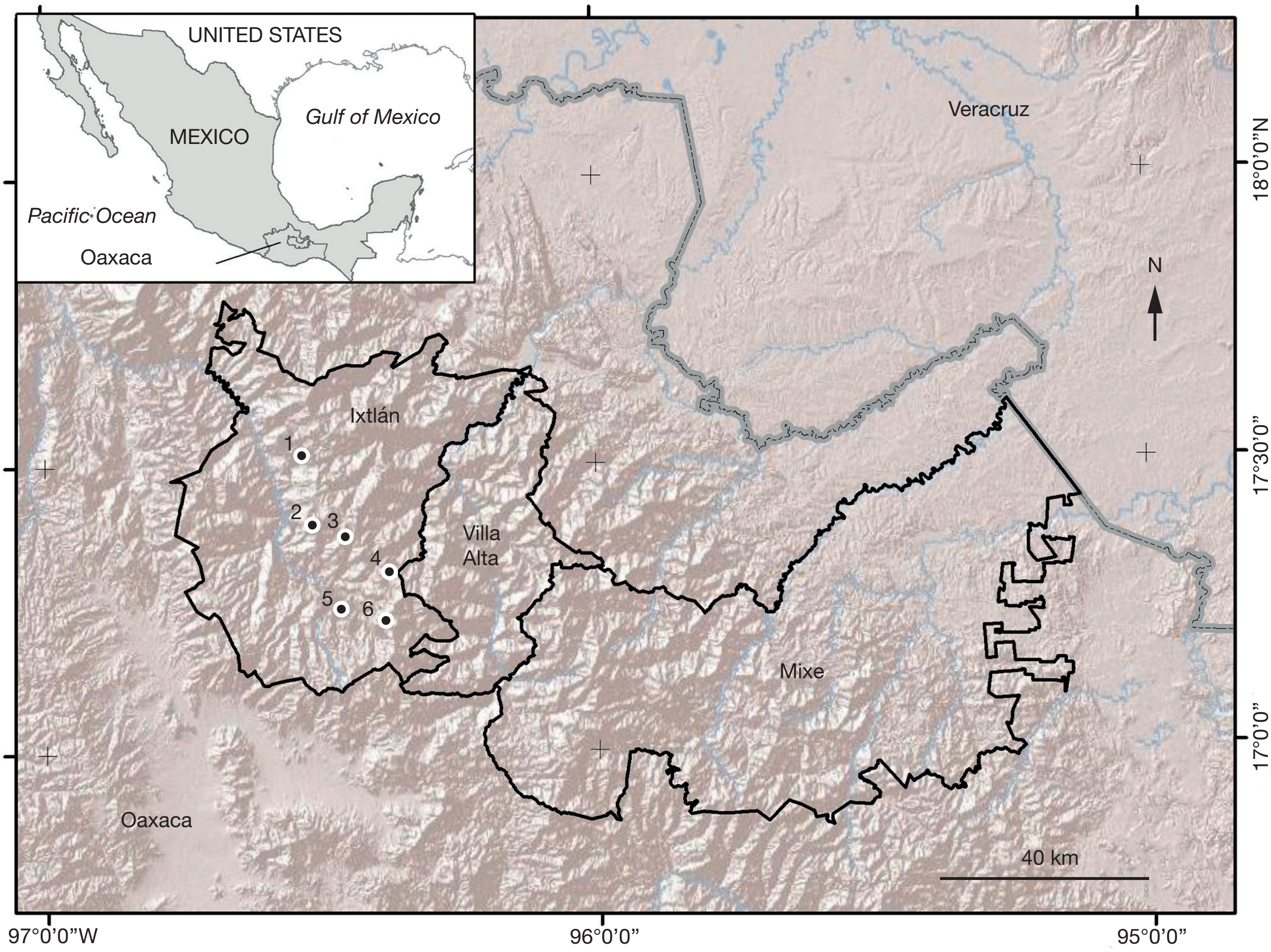

Fig. 1. — The geographical location of the Sierra Norte of Oaxaca (inset) and its three political-administrative districts: Ixtlán (Sierra Juárez), Mixe and Villa Alta. The gray dotted line indicates the border between the states of Oaxaca and Veracruz. The numbers indicate the fieldwork study sites in the Ixtlán district: **1**, San Juan Luvina (17°31'7.1"N, 96°31'59.4"W); **2**, San Juan Evangelista Analco (17°23'56"N, 96°30'45.3"W); **3**, Ixltán de Juárez (17°22'42.4"N, 96°27'33.4"W); **4**, Capulalpam de Méndez (17°18.826'N, 96°22.658'W); **5**, Santa Catarina Lachatao (17°15'7.90"N, 96°27'58.50"W); and **6**, Santa María Yavesía (17°13'43.9"N, 96°23'15.60"W).

turbance in the region include deforestation due to land-use conversion (Gómez-Mendoza *et al.* 2006) and strong cyclic winds (Clark-Tapia *et al.* 2016).

Study design

We searched for moss georeferenced records in the state of Oaxaca in the databases of the Global Biodiversity Information Facility (GBIF 2020), the Consortium of North American Bryophyte Herbaria (CNABH 2020), and the Mexican National Herbarium (IBUNAM 2020). We used ArcMap 10.7 (Esri 2019) to determine which records were located in the pine-oak vegetation. To delimit the pine-oak vegetation area, we used the physio-structural vegetation data of Mexico proposed by Balduzzi & Tomaseli (1979), and the vegetation and land use data from CONABIO (1998).

To complement the moss checklist, we conducted fieldwork in six sites in the Ixtlán de Juárez district from January 2016 to July 2017. We chose this area due to its good level of forest conservation. In these sites, we sampled: 1) terrestrial mosses, (growing on substrates such as gravel, soil, or decaying wood), and 2) epiphytes growing on *Quercus* trees. We focused on *Quercus* because it is the most abundant genus of trees after *Pinus* L. (Torres-Colín 2004) and have a stronger association with bryophytes (Palmer 1986; Gradstein *et al.* 2003). To sample terrestrial mosses and obtain information about their species richness and abundance, we randomly established ten quadrats of 1 m^2 in each study site (60 in total). The area of the quadrats was divided into 100 cells of 10 cm^2. Abundance was estimated by calculating the percentage of cells occupied by each species (Kimmerer 2005). In the case of epiphytes, we sampled the oak with a diameter at breast height >30 cm closest to each of the quadrats of 1 m^2 (60 trees in total). We set a micro quadrat of 20 cm^2 at the height of 1.6 m on one side of each trunk, at a random cardinal position (N, S, E, W). To estimate the abundance of the epiphytic mosses, we applied the same criterium as for the terrestrial ones but using a 20 cm^2 quadrat. To collect those species that did not appear in the sampling quadrats, we did floristic habitat sampling (Newmaster *et al.* 2005).

To compare the moss flora from the Sierra Norte with that occurring in other pine-oak forests in Mexico, we reviewed the studies of Alfaro Omaña and Castillo Delgadillo (1986)

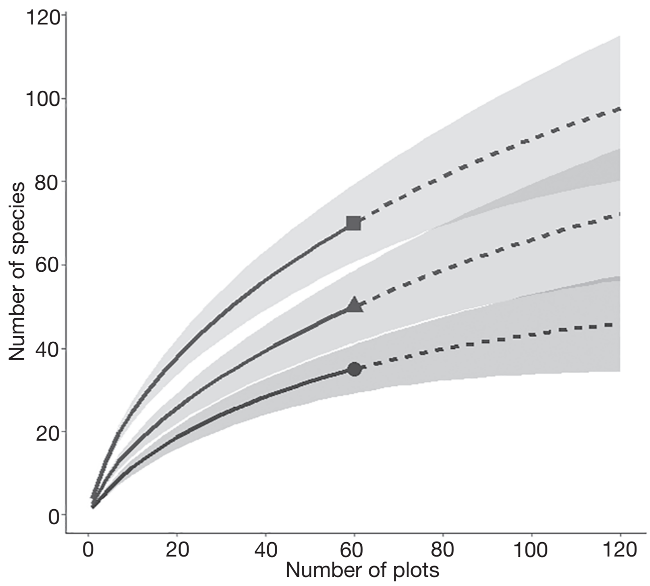

Fig. 2. — Rarefaction and extrapolation curves showing the total number of moss species (■), terrestrial (▲), and epiphytes (●). The dotted lines correspond to extrapolations and the shaded areas to the 95% confidence intervals.

in the Sierra de Pachuca, Hidalgo, Herrera-Paniagua *et al.* (2018) in Sierra de Lobos, Guanajuato, and Contreras Mora (1986) in the center of the Veracruz state. These studies are based on floristic sampling and represent the only ones carried out in other pine-oak forests in Mexico.

SPECIES DETERMINATION

All the samples collected were determined to the species level using the taxonomic keys of Allen (1994, 2002, 2010), Buck (1998), Gradstein *et al.* (2001), and Sharp *et al.* (1994) and following the species nomenclature proposed in LATMOSS (Delgadillo 2010), and the classification proposed by Goffinet & Buck (2020) at the family level. The samples were deposited in the Herbarium of the Universidad Michoacana de San Nicolás de Hidalgo (EBUM) and the National Herbarium of the Universidad Nacional Autónoma de México (MEXU).

DATA ANALYSES

We use the data from the 60 sampling sites to estimate the α and β diversity and evaluate the community structure. For α diversity and calculate sampling effort, rarefaction / extrapolation (R/E) curves with 95% confidence intervals were built using the zero-order Hill number (q = 0). Hill numbers represent a statistically rigorous alternative to other diversity indices (Chao *et al.* 2014). The β diversity was assessed using the method proposed by Carvalho *et al.* (2012), which assumes that species turnover (βtotal) is determined by species replacement (βrepl) and richness differences between sites (βriq). Rank-abundance curves were performed to highlight common and rare species (Magurran 2004). These analyzes were conducted using all mosses species but also using terrestrial and epiphytes guilds separately.

We performed a non-metric multidimensional scale analysis (NMDS) using Euclidean dissimilarity matrices to compare the composition of the terrestrial moss and epiphyte communities using the 60 sites. Before the analysis, we transform the percentage coverage values by applying the square root to have a normal distribution (McCune *et al.* 2002). After, we performed a similarity analysis (ANOSIM test) with 999 permutations to assess significant differences.

We used the data obtained from fieldwork and online databases to assess the degree of similarity of the moss richness of the Sierra Norte with other pine-oak forests in Mexico. To evaluate the similarity between forests a hierarchical grouping dendrogram was performed using the simple agglomeration method. Finally, to evaluate if the pine-oak forests' moss diversity and the geographical distance between them were related, we conducted a Mantel test (Legendre & Legendre 2012).

We performed all the analyses in R v.4.0.0 (R Core Team 2020) using the package iNEXT 2.0.14 (Hsieh *et al.* 2016) for the Chao 2 index and the R / E curves, the BAT package (Cardoso *et al.* 2017) to calculate β diversity, the stats package for the cluster analysis (R Core Team 2020), the BiodiversityR package (Kindt & Coe 2005) for the NMDS and ANOSIM test, and the Vegan 2.4-4 (Okansen *et al.* 2018) package to the Mantel test.

RESULTS

Overall, we compiled evidence of the occurrence of 339 species, 168 genera, and 52 families of mosses in the pine-oak forest in the Sierra Norte region (Appendix 1). The families with the highest number of species were Pottiaceae (41), Leucobryaceae (25), Bartramiaceae (22), Orthotrichaceae (18), Brachytheciaceae (17), Bryaceae (17), Dicranaceae (15), Hypnaceae (14), and Polytrichaceae (10); the remaining families (43) were represented by one to nine species. The genera with the highest richness was *Campylopus* Brid. (14), *Bryum* Hedw. (9), *Fissidens* Hedw. (9), and *Philonotis* Brid. (7); the rest (164) had less than six species.

As a result of the fieldwork conducted in the Ixtlan district, 50 terrestrial and 35 epiphytic species were found. From these species, 15 were epiphytic or growing in some terrestrial microhabitat. Some species were recorded growing on *Quercus* but also in terrestrial substrates such as *Braunia squarrulosa* (Hampe) Müll. Hal., *Leptodontium viticulosoides* P.Beauv.) Wijk & Margad., *Mittenothamnium reptans* (Hedw.) Cardot, *Sematophyllum adnatum* (Michx.) E.Britton, and *Thuidium delicatulum* (Hedw.) Schimp. Based on richness results and the rarefaction/extrapolation analysis, it is estimated that in the pine-oak forest of this district, there can be up to 131 species of mosses (53% of completeness, Chao 2 analysis). If the diversity of terrestrial and epiphytic mosses is analyzed separately, the richness is estimated to be 102 and 53, respectively. Therefore 49-66% of the species were recorded in each case. The lack of overlapping confidence intervals in the rarefaction/extrapolation curves suggests the existence of significant differences between the richness of these guilds (observed richness) (Fig. 2).

The analysis of the β diversity revealed a high turnover of species for all mosses together. This was also true when distinguishing between terrestrial and epiphyte species (βtotal = *c.* 93%). In all three cases, more than 50% of the replacement is explained by the substitution of species between sites (βrepl) and to a lesser extent (between 29 and 39%) by differences in richness (βrich) (Fig. 3).

Overall, the rank-abundance graph shows that moss communities were dominated by a few common species, with a large number of species having a relatively low abundance. The terrestrial mosses have more species with low abundances than epiphytic ones. Besides, some terrestrial-epiphytic species, such as *Prionodon luteovirens* (Taylor) Mitt. and *Zygodon viridissimus* (Dicks.) Brid., were not abundant when terrestrial but, were more abundant as epiphytes (Fig. 4).

Among the terrestrial mosses common species with a high abundance stand out *Thuidium delicatulum*, *Mittenothamnium reptans*, *Hypnum amabile* (Mitt.) Hampe, *Leptodontium viticulosoides,* and *Dicranum sumichrastii* Duby. In contrast, among the rare species were *Homomallium sharpii* Ando & Higuchi, *Hyophila involuta* (Hook.) A.Jaeger, *Orthotrichum hortoniae Vitt*, *Porotrichum longirostre* (Hook.) Mitt., and *Symblepharis vaginata* (Hook. ex Harv.) Wijk & Margad. In the case of epiphytic mosses, common species included *Braunia squarrulosa*, *Neckera chlorocaulis* Müll. Hal., *Prionodon luteovirens* (Taylor) Mitt., *Zygodon viridissimus* (Dicks.) Brid., and *Leucodon curvirostris* Hampe; while those rares were *Brachythecium ruderale* (Brid.) W.R.Buck, *Hygrohypnum robinsonii* H.A.Crum, *Zygodon ehrenbergii* Müll. Hal., *Cyrtohypnum schistocalyx* (Müll. Hal.) W.R.Buck & H.A.Crum, and *Porotrichum longirostre* (Hook.) Mitt.

The NMDS ordination indicates that terrestrial and epiphytic mosses communities share some species with proportionally similar abundance (Fig. 5). However, a great part of the species from epiphytic and terrestrial microhabitats are exclusive. Differences between terrestrial and epiphytic communities are supported by the ANOSIMR test ($R = 0.11$, $p = 0.001$). The stress value (0.25) indicates good stability in the ordination configuration (Dexter *et al.* 2018).

Cluster analysis reveals a grouping of Mexico's pine-oak forests based on their species richness but not a latitudinal gradient of the sampling areas (Fig. 6). Mantel test showed no correlation between the moss diversity of the pine-oak forests and their geographical distance ($r = 0.18$, $p = 0.46$).

DISCUSSION

The pine-oak forest in the Sierra Norte of Oaxaca has a high diversity of mosses representing 72% of the moss flora of the state and 34% of the country. This work shows that pine-oak forests support a much larger number of species than those reported by previous studies (around 100 species). Based on the extent of unexplored areas in Mexico (Sánchez *et al.* 2003; Delgadillo 2014), results of previous studies, and the information presented here, the moss flora of temperate pine-oak forests likely exceed 400 species. Further exploration of temperate forests in northern regions, such as the Sierra Madre Oriental and Occidental, can significantly increase such number.

We found well-distributed moss families across Mexico are the most speciose in the pine-oak forests (Pottiaceae, Bryaceae, Dicranaceae, Fissidentaceae, and Orthotrichaceae), as reported by Delgadillo (2014). These families include some widely distributed species in the country, such as *Syntrichia obtusissima* (Müll. Hal.) R.H.Zander, *Bryum billarderii* Schwägr., *Campylopus pilifer* Brid., and *Fissidens asplenioides* Hedw. However, there are differences in species composition and richness between the pine-oak forests studied here. The differences in richness in the Sierra Norte of Oaxaca compared to other regions of Mexico may be related to the intensity of sampling in those areas (Fig. 6). The Sierra Norte of Oaxaca has been visited by national and international botanists for several years, which has resulted in a good representation of its flora in the databases consulted. Other factors that could explain moss species dissimilarities with the others pine-oak forests are differences in the studied area size, their conservation state, and their variation in latitude and altitude. For example, the three studies compared were conducted in smaller areas compared with that of Sierra Norte of Oaxaca. Also, Herrera-Paniagua *et al.* (2018) and Contreras Mora (1986) indicate that Sierra de Lobos and other localities in the center of Veracruz had extensive disturbances that include land use changes for agriculture and livestock. Finally, the areas from the three studies are located in a latitudinal gradient along Mexico and show an altitudinal variation from 10-700 m in the center of Veracruz (Contreras Mora 1986) to 2400-3050 m in the Sierra de Pachuca, Hidalgo (Alfaro Omaña & Castillo Delgadillo 1986). In the case of the Sierra Norte of Oaxaca, there are still large areas in the region that have not been explored, and that could increase the list of mosses, for example, the southern part of the Villa Alta district and the center and the east of the Mixe district (Fig. 1). Studies on the moss flora are necessary to improve our knowledge about regional biodiversity and species distributions, especially in a forest with large conserved areas like the Sierra Norte of Oaxaca (Navarro Cerrillo *et al.* 2018; Cornwell *et al.* 2019).

The high richness of mosses in the temperate forest in northern Oaxaca follows that of its vascular plants, both terrestrial and epiphytic (Challenger 2003). The pine-oak moss diversity in Oaxaca also includes national endemics such as *Acritodon nephophilus* H.Rob., *Anacamptodon compactus* (Thér.) W.R.Buck, *Didymodon incrassatolimbatus* Cardot, *Entodon abbreviatus* (Schimp.) A.Jaeger, *Entodon brevirostris* (Schimp.) A.Jaeger, and *Homomallium sharpii* Ando & Higuchi (Delgadillo *et al.* 2019). This diversity may be due to the environmental heterogeneity caused by the topography and the mixing with other contiguous vegetation types with extensive conserved areas such as the cloud forest (Ponce-Reyes *et al.* 2012; Antonelli *et al.* 2018). In the pine-oak

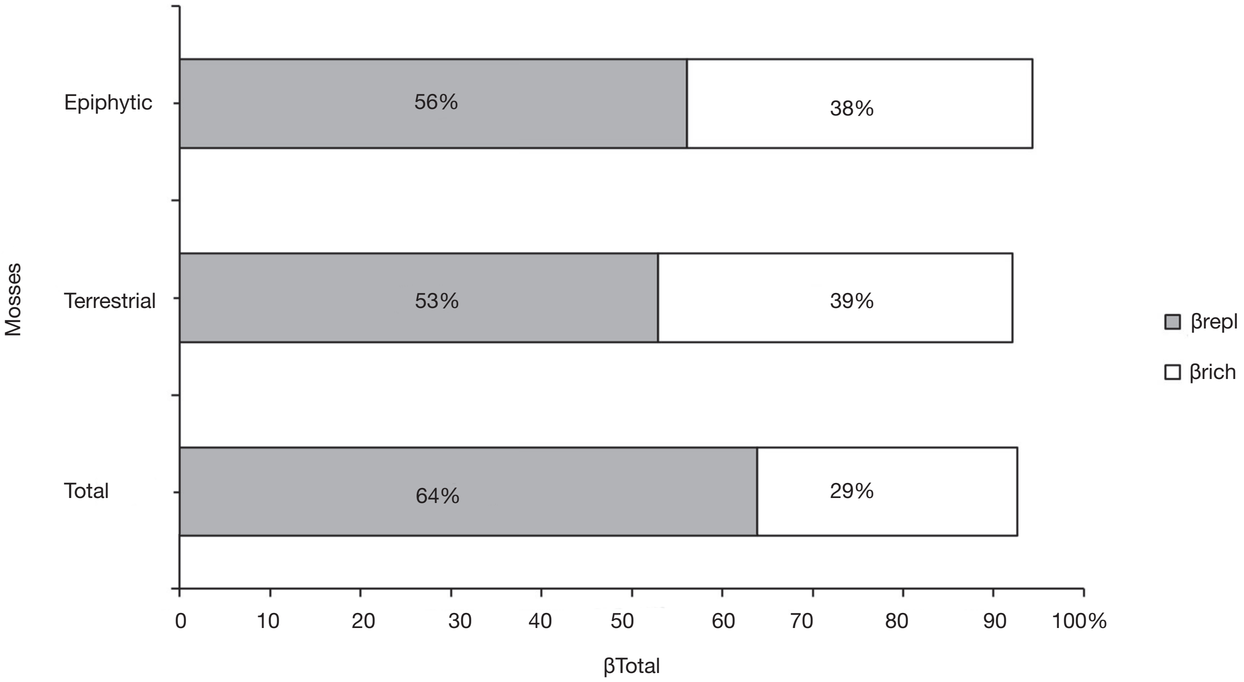

FIG. 3. — Partition of total, terrestrial and epiphytic mosses β diversity in the pine-oak forest of the Ixtlán de Juárez district, Oaxaca. **βrepl**, species replacement; **βrich**, richness differences between sites.

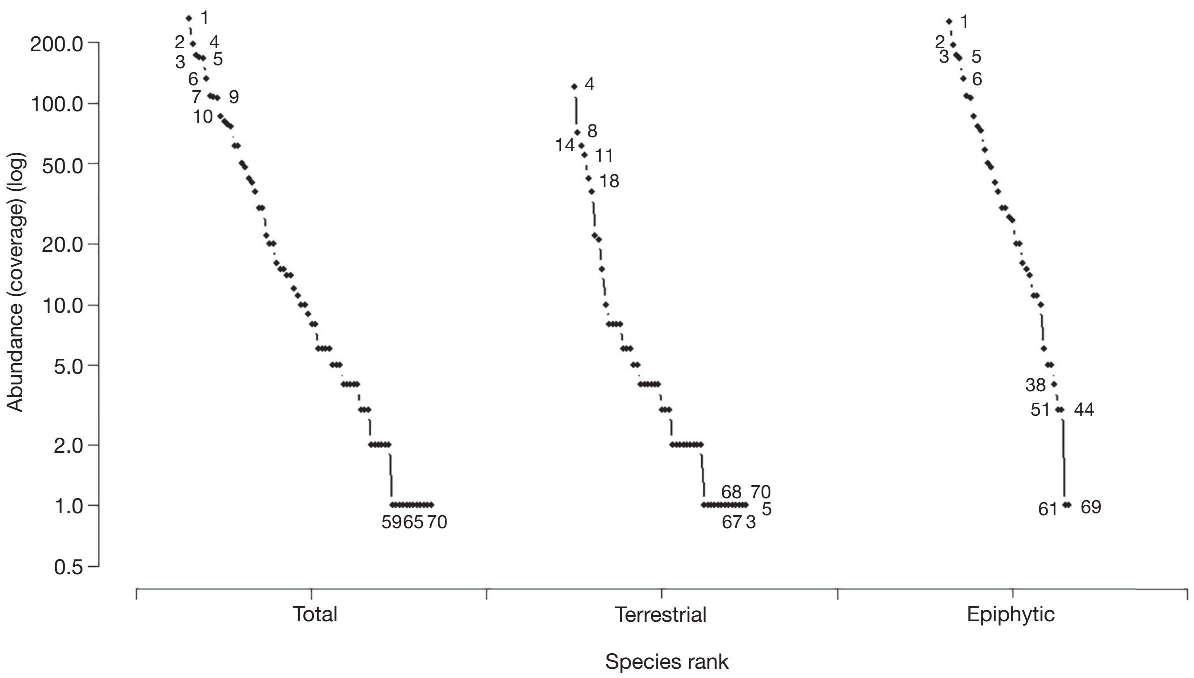

FIG. 4. — Rank-abundance graph of the moss community in general (total) as well as the terrestrial and epiphytic mosses of the pine-oak forest of the Sierra Norte, Oaxaca. Coverage values represent the abundance of species in cm^2. Numbers indicate the species: **1**, *Braunia squarrulosa*; **2**, *Neckera chlorocaulis*; **3**, *Prionodon luteovirens*; **4**, *Thuidium delicatulum*; **5**, *Zygodon viridissimus*; **6**, *Leucodon curvirostris*; **7**, *Pylaisia falcata*; **8**, *Mittenothamnium reptans*; **9**, *Meteorium illecebrum*; **10**, *Prionodon densus*; **11**, *Leptodontium viticulosoides*; **14**, *Hypnum amabile*; **18**, *Dicranum sumichrastii*; **38**, *Brachythecium ruderale*; **44**, *Zygodon ehrenbergii*; **51**, *Hygrohypnum robinsonii*; **59**, *Brachytecium oxycladon*; **60**, *Bryum huillense*; **61**, *Cyrto-hypnum schistocalyx*; **62**, *Dicranum scoparium*; **63**, *Heterophyllum affine*; **64**, *Fissidens elegans*; **65**, *Holomitrium arboreum*; **66**, *Homomallium sharpii*; **67**, *Hyophila involuta*; **68**, *Orthotrichum hortoniae*; **69**, *Porotrichum longirostre*; **70**, *Symblepharis vaginata*.

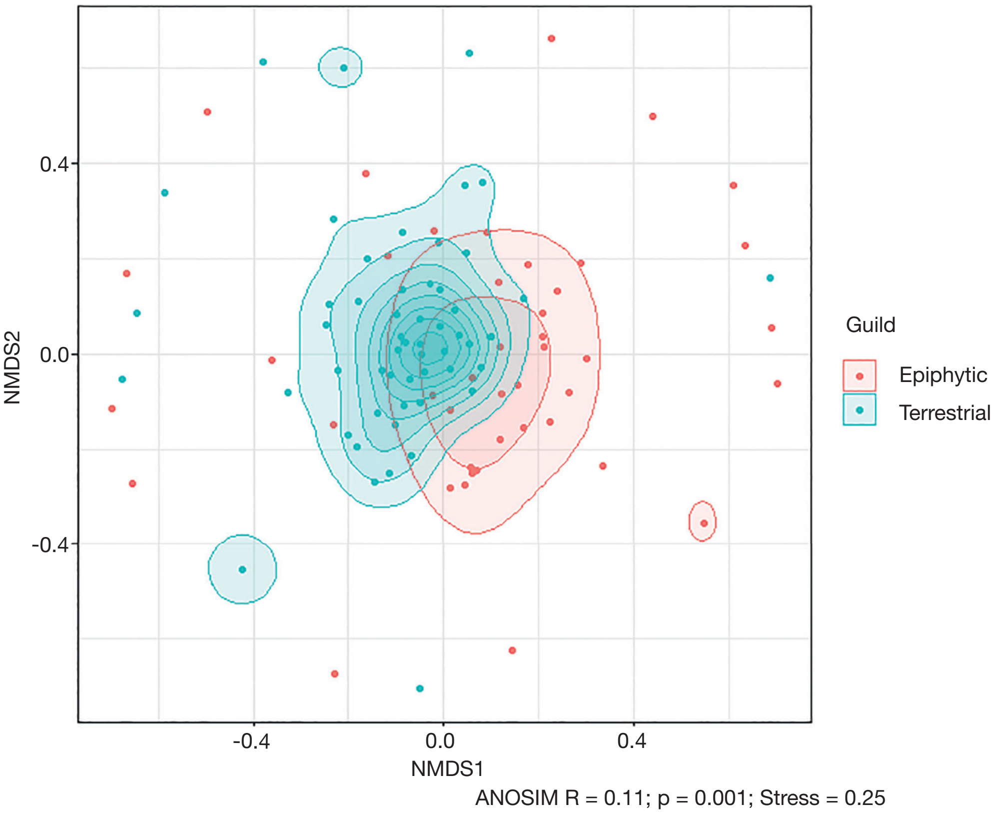

FIG. 5. — Non-metric multidimensional scaling (**NMDS**) of the terrestrial and epiphytic mosses communities in the pine-oak forest in the Ixtlan district, Sierra Norte of Oaxaca. The inner circles in each group (guild) indicate the similarity of species based on their abundance (coverage).

forest, we recorded sixty-eight percent of the moss species of the nearby cloud forest (Hernández-Rodríguez & Aguirre Hidalgo 2020). Some representative species shared between the cloud forest and the pine-oak forest include epiphytes like *Acroporium longirostre* (Brid.) W.R.Buck, *Adelothecium bogotense* (Hampe) Mitt., *Dendropogonella rufescens* (Schimp.) E.Britton, and *Pilotrichella flexilis* (Hedw.) Ångstr. Some terrestrial species shared include *Dicranum frigidum* Müll. Hal., *Fissidens polypodioides* Hedw., *Mittenothamnium reptans* (Hedw.) Cardot, and *Thuidium delicatulum* (Hedw.) Schimp. Locally, the variation of this diversity, as well as the high turnover (βtotal) and replacement (βrepl) of terrestrial and epiphytic species, may be related to the heterogeneity of soil microhabitats and ecological niches created by pines and oaks (Rzedowski 1978; Großmann *et al.* 2018).

On the other hand, the rank abundance graphs suggest that the impact of ecological processes, such as competition and niche occupation, might be different for terrestrial mosses and epiphytic mosses, resulting in communities with different structures (Fig. 4). The dominance of a relatively small group of terrestrial species (common) and a more significant number of species with low abundance (rare) indicate that processes such as competition could be stronger on the forest floor. In the epiphytic mosses, the establishment on the oaks is more random and likely with less competition (Whittaker 1965). Low competition is expected to occur due to greater vertical availability of niches related to favorable microconditions, such as low water stress, favoring epiphytic bryophyte colonization (Mazimpaka & Lara 1995; Ezer *et al.* 2009). Due to these patterns, the conservation of microhabitats in the forest floor and the oaks are essential to maintain the structure of their communities and the presence of common and rare species. The preservation of abundant species has important implications due to the fact they carry out critical ecological processes as favouring the establishment of vascular plants and the functioning of water cycles (García-Ávila 1998; Ah-Peng *et al.* 2017). In the case of rare species, it is necessary to conserve them since they are the most likely to disappear due to their specific habitat requirements and changes in their environment. To gain a better understanding of the rarity and commonness of species and to have a more complete inventory, the exploration of microhabitats in rocky areas, caves, and seasonal and permanent streams is highly necessary. In our study, the collection of epiphytic mosses was focused on oak trees, but other trees and shrub species can support moss species. For example, *Leucobryum antillarum* Schimp. ex Besch. and *Pyrrhobryum spiniforme* (Hedw.) Mitt. were only collected at the bases of mature pines where the bark is thicker, humidity is high and resin that prevents moss establishment is not abundant. Another example is *Entodon abbreviatus,* which represents a new record for the study area; this species was collected only on a shrub of the genus *Baccharis* L.

The results of this study reaffirm that the Sierra Norte of Oaxaca is an area of high floristic diversity, including for

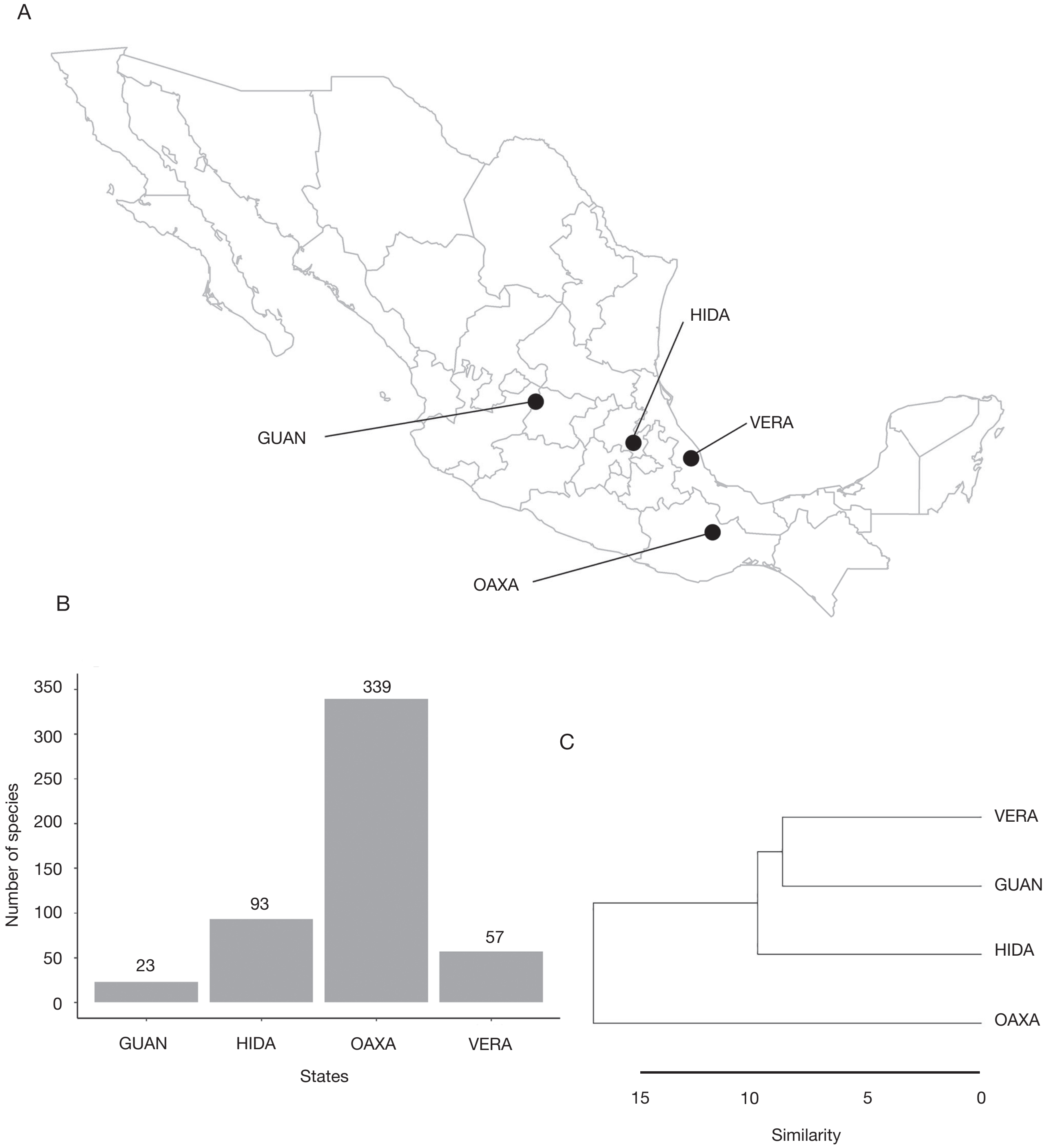

Fig. 6. — **A**, **B**, Moss richness of pine-oak forests in four states of Mexico; **C**, grouping based on their richness of moss species according to cluster analysis. Abbreviations: **OAXA**, Sierra Norte of Oaxaca; **VERA**, Center of Veracruz state; **HIDA**, Sierra de Pachuca, Hidalgo; **GUAN**, Sierra de Lobos, Guanajuato.

non-vascular plants. This information can help maintain its status as a plant conservation area and promote natural areas' protection (Cabrera *et al.* 2000; Volvenko 2012; Suárez-Mota *et al.* 2018). Finally, with information from previous studies, this work provides a floristic list of the mosses recorded for temperate pine-oak forests in Mexico. For the Sierra Norte of Oaxaca forest, we present parameters about its moss richness, species turnover, abundance, and community structure. We expect this work will serve as a reference for studies in these forests in other regions of Mexico. In this way, it contributes to the knowledge of the flora and ecology of bryophytes in ecosystems where they are usually neglected.

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APPENDIX

Appendix 1. Species checklist of mosses for four pine-oak forest in Mexico: **OAXA**, Sierra Norte de Oaxaca; **VERA**, Center of Veracruz state (Contreras, 1986); **HIDA**, Sierra de Pachuca, Hidalgo (Alfaro & Castillo, 1986) and **GUAN**, Sierra de Lobos, Guanajuato (Herrera-Paniagua *et al.* 2018). * Indicate endemic species for Mexico. The number 1 indicates the presence of the species.

Families and species	HIDA	GUAN	VERA	OAXA
Amblystegiaceae	–	–	–	–
**Anacamptodon compactus* (Thér.) W.R.Buck	–	–	–	1
Campyliadelphus chrysophyllus (Brid.) R.S.Chopra	–	–	–	1
Campylium hispidulum (Brid.) Mitt.	1	–	–	1
Cratoneuron filicinum (Hedw.) Spruce	–	–	–	1
Drepanocladus aduncus (Hedw.) Warnst.	–	–	–	1
Hygroamblystegium varium (Hedw.) Mönk.	–	–	–	1
Hygrohypnum robinsonii H.A.Crum	–	–	–	1
Andreaeaceae	–	–	–	–
Andreaea rupestris Hedw.	–	–	–	1
Anomodontaceae	–	–	–	–
Anomodon attenuatus (Hedw.) Huebener	–	–	–	1
Anomodon minor (Hedw.) Lindb.	–	–	–	1
Anomodon viticulosus (Hedw.) Hook. & Taylor	–	–	–	1
Herpetineuron toccoae (Sull. & Lesq.) Cardot	–	–	–	1
Bartramiaceae	–	–	–	–
Anacolia laevisphaera (Taylor) Flowers	1	1	–	1
Bartramia brevifolia Brid.	–	–	–	1
Bartramia halleriana Hedw.	–	–	–	1
Bartramia ithyphylla Brid.	–	–	–	1
Bartramia microstoma Mitt.	1	–	–	–
Bartramia potosica Mont.	–	–	–	1
Breutelia brittoniae Renauld & Cardot	–	–	–	1
Breutelia chrysea (Müll. Hal.) A.Jaeger	–	–	–	1
Breutelia inclinata (Hampe & Lorentz) A.Jaeger	–	–	–	1
Breutelia jamaicensis (Mitt.) A.Jaeger	–	–	–	1
Breutelia subarcuata (Müll. Hal.) Schimp.	–	–	–	1
Breutelia tomentosa (Sw. ex Brid.) A.Jaeger	1	–	–	1
Conostomum tetragonum (Hedw.) Lindb.	–	–	–	1
Leiomela bartramioides (Hook.) Paris	–	–	–	1
Neosharpiella aztecorum H.Rob. & Delgad.	–	–	–	1
Philonotis elongata (Dism.) H.A.Crum & Steere	–	–	–	1
Philonotis glaucescens (Hornsch.) Broth.	–	–	–	1
Philonotis hastata (Duby) Wijk & Margad.	–	–	–	1
Philonotis longiseta (Michx.) E.Britton	–	–	–	1
Philonotis marchica (Hedw.) Brid.	–	–	–	1
Philonotis sphaerocarpa (Hedw.) Brid.	–	–	1	1
Philonotis uncinata (Schwägr.) Brid.	–	–	1	1
Brachytheciaceae	–	–	–	–
Aerolindigia capillacea (Hornsch.) M. Menzel	–	–	–	1
Brachythecium acuminatum (Hedw.) Austin	–	–	–	1
Brachythecium cirriphylloides K.D. McFarland	–	–	–	1
Brachythecium oxycladon (Brid.) A.Jaeger	–	–	–	1
Brachythecium plumosum (Hedw.) Schimp.	–	–	–	1
Brachythecium ruderale (Brid.) W.R.Buck	–	–	–	1
Brachythecium salebrosum (Hoffm. ex F.Weber & D.Mohr) Schimp.	1	–	–	–
Kindbergia praelonga (Hedw.) Ochyra	–	–	–	1
Palamocladium leskeoides (Hook.) E.Britton	1	–	–	1
Rhynchostegium pulchellum (Hedw.) H.Rob.	–	–	–	1
Rhynchostegium riparioides (Hedw.) Cardot	–	–	–	1
Rhynchostegium scariosum (Taylor) A.Jaeger	–	–	–	1
Rhynchostegium semiscabrum (E.B.Bartram) H Rob.	–	–	–	1
Rhynchostegium serrulatum (Hedw.) A.Jaeger	–	–	1	–
Squamidium leucotrichum (Taylor) Broth.	–	–	–	1
Squamidium nigricans (Hook.) Broth.	–	–	–	1
Zelometeorium patulum (Hedw.) Manuel	–	–	–	1
Bruchiaceae	–	–	–	–
Trematodon longicollis Michx.	–	–	–	1
Bryaceae	–	–	–	–
Anomobryum concinnatum (Spruce) Lindb.	1	–	–	1
Anomobryum julaceum (Schrad. ex G.Gaertn., B.Mey. & Scherb.) Schimp.	–	–	–	1
Anomobryum prostratum (Müll. Hal.) Besch.	1	–	–	–
Brachymenium fabronioides (Müll. Hal.) Kindb.	–	–	–	1
Brachymenium mexicanum Mont.	–	–	1	1
Brachymenium systylium (Müll. Hal.) A.Jaeger	–	–	1	1

APPENDIX 1. — Continuation.

Families and species	HIDA	GUAN	VERA	OAXA
Bryum argenteum Hedw.	1	–	1	1
Bryum billarderii Schwägr.	1	1	–	1
Bryum capillare Hedw.	–	–	1	1
Bryum chryseum Mitt.	–	1	1	1
Bryum densifolium Brid.	–	–	1	–
Bryum erythroloma (Kindb.) Syed	1	–	–	–
Bryum leptotorquescens Müll. Hal. ex Broth.	–	–	–	1
Bryum limbatum Müll. Hal.	–	–	–	1
Bryum procerum Schimp. ex Besch.	–	–	–	1
Bryum pseudocapillare Besch.	–	–	1	–
Bryum pseudotriquetrum (Hedw.) G.Gaertn., B.Mey. & Scherb.	–	–	–	1
Bryum richardsii Sharp	–	–	–	1
Rhodobryum beyrichianum (Hornsch.) Paris	–	–	1	1
Rhodobryum huillense (Welw. & Duby) Touw	–	–	–	1
Rhodobryum roseum (Hedw.) Limpr.	1	–	–	1
Calymperaceae	–	–	–	–
Calymperes palisotii Schwägr.	–	–	1	–
Syrrhopodon circinatus (Brid.) Mitt.	–	–	–	1
Syrrhopodon incompletus Schwägr.	–	–	1	1
Syrrhopodon prolifer Schwägr.	–	–	–	1
Cryphaeaceae	–	–	–	–
Cryphaea apiculata Schimp.	–	–	–	1
Cryphaea attenuata Schimp.	–	–	–	1
Cryphaea filiformis (Hedw.) Brid.	–	–	–	1
Cryphaea jamesonii Taylor	–	–	–	1
Cryphaea patens Hornsch. ex Müll. Hal.	1	–	–	1
Dendropogonella rufescens (Schimp.) E.Britton	–	–	–	1
Schoenobryum concavifolium (Griff.) Gangulee	–	–	1	1
Sphaerotheciella pachycarpa (Schimp. ex Besch.) Manuel	–	–	–	1
Sphaerotheciella pinnata (Schimp.) Manuel	–	–	–	1
Daltoniaceae	–	–	–	–
Adelothecium bogotense (Hampe) Mitt.	–	–	–	1
Daltonia gracilis Mitt.	–	–	–	1
Daltonia longifolia Taylor	–	–	–	1
Daltonia pulvinata Mitt.	–	–	–	1
Daltonia stenophylla Mitt.	–	–	–	1
Daltonia tenuifolia Mitt.	–	–	–	1
Leskeodon cubensis (Mitt.) Thér.	–	–	–	1
Leskeodon longipilus (Besch.) E.B. Bartram	–	–	–	1
Dicranaceae	–	–	–	–
Anisothecium vaginatum (Hook.) Mitt.	–	–	–	1
Anisothecium varium (Hedw.) Mitt.	–	–	–	1
Aongstroemia julacea (Hook.) Mitt.	–	–	–	1
Aongstroemia orientalis Mitt.	1	–	–	1
Dicranella brachyblepharis (Müll. Hal.) Mitt.	–	–	–	1
Dicranella hilariana (Mont.) Mitt.	–	–	–	1
Dicranum flagellare Hedw.	1	–	–	1
Dicranum frigidum Müll. Hal.	1	–	–	1
Dicranum rhabdocarpum Sull.	–	–	–	1
Dicranum scoparium Hedw.	–	–	–	1
Dicranum sumichrastii Duby	–	–	–	1
Holomitrium arboreum Mitt.	–	–	–	1
Holomitrium pulchellum Mitt.	–	–	–	1
Holomitrium terebellatum Müll. Hal.	–	–	–	1
Leucoloma serrulatum Brid.	–	–	–	1
Diphysciaceae	–	–	–	–
Diphyscium foliosum (Hedw.) D.Mohr	–	–	–	1
Ditrichaceae	–	–	–	–
Ceratodon purpureus (Hedw.) Brid.	1	–	–	1
Ditrichum gracile (Mitt.) Kuntze	–	–	–	1
Ditrichum rufescens (Hampe) Hampe	–	–	–	1
Encalyptaceae	–	–	–	–
Encalypta ciliata Hedw.	1	–	–	–
Entodontaceae	–	–	–	–
**Entodon abbreviatus* (Schimp.) A.Jaeger	–	–	–	1
Entodon beyrichii (Schwägr.) Müll. Hal.	1	–	1	1
**Entodon brevirostris* (Schimp.) A.Jaeger	–	–	–	1
Entodon hampeanus Müll. Hal.	–	–	–	1
Entodon jamesonii (Taylor) Mitt.	–	–	–	1
Entodon macropodus (Hedw.) Müll. Hal.	–	–	1	1

Appendix 1. — Continuation.

Families and species	HIDA	GUAN	VERA	OAXA
Entodon serrulatus Mitt.	–	–	–	1
Erythrodontium longisetum (Hook.) Paris	–	–	1	1
Erythrodontium squarrosum (Hampe) Müll. Hal. ex Paris	–	–	–	1
Fabroniaceae	–	–	–	–
Fabronia ciliaris (Brid.) Brid.	1	–	1	1
Fabronia macroblepharis Schwägr.	–	–	–	1
Fissidentaceae	–	–	–	–
Fissidens asplenioides Hedw.	1	–	1	1
Fissidens biformis Mitt.	–	–	1	–
Fissidens bryoides Hedw.	1	–	1	1
Fissidens crispus Mont.	–	1	–	1
Fissidens dissitifolius Sull.	–	–	1	–
Fissidens elegans Brid.	–	–	1	1
Fissidens flaccidus Mitt.	–	–	1	–
Fissidens goyazensis Broth.	–	–	1	–
Fissidens grandifrons Brid.	–	–	–	1
Fissidens hyalinus Wilson & Hook.	–	–	–	1
Fissidens minutus Thwaites & Mitt.	–	–	1	–
Fissidens mollis Mitt.	–	–	1	–
Fissidens palmatus Hedw.	–	–	1	–
Fissidens perfalcatus Broth.	–	–	1	–
Fissidens polypodioides Hedw.	–	–	–	1
Fissidens rigidulus Hook. f. & Wilson	–	–	–	1
Fissidens serratus Müll. Hal.	–	–	–	1
Fissidens sublimbatus Grout	–	1	1	–
Fissidens zollingeri Mont.	–	–	1	–
Flowersia campylopus (Schimp.) D.G.Griffin & W.R.Buck	–	–	–	1
Funariaceae	–	–	–	–
Entosthodon obtusifolius Hook. f.	–	1	–	1
Funaria apiculatopilosa Cardot	1	–	–	–
Funaria hygrometrica Hedw.	1	–	1	1
Grimmiaceae	–	–	–	–
Grimmia longirostris Hook.	1	1	–	1
Grimmia ovalis (Hedw.) Lindb.	1	–	–	–
Grimmia pilifera P. Beauv.	1	–	–	1
**Grimmia pulla* Cardot	1	–	–	–
Grimmia trichophylla Grev.	–	–	–	1
Racomitrium crispipilum (Taylor) A.Jaeger	–	–	–	1
Racomitrium heterostichum (Hedw.) Brid.	–	–	–	1
Racomitrium subsecundum (Hook. & Grev. ex Harv.) Mitt. & Wilson	–	–	–	1
Schistidium apocarpum (Hedw.) Bruch & Schimp.	–	–	–	1
Hedwigiaceae	–	–	–	–
Braunia imberbis (Sm.) N.Dalton & D.G.Long	–	–	–	1
Braunia secunda (Hook.) Bruch & Schimp.	1	1	–	1
Braunia squarrulosa (Hampe) Müll. Hal.	1	–	–	1
Hedwigia ciliata (Hedw.) P.Beauv.	1	–	–	1
Hedwigidium integrifolium (P. Beauv.) Dixon	1	–	–	–
Hookeriaceae	–	–	–	–
Hookeria acutifolia Hook. & Grev.	–	–	–	1
Hylocomiaceae	–	–	–	–
Ctenidium malacodes Mitt.	–	–	–	1
Loeskeobryum brevirostre (Brid.) M.Fleisch.	–	–	–	1
Puiggariopsis aurifolia (Mitt.) M. Menzel	–	–	–	1
Schofieldiella micans (Mitt.) W.R.Buck	–	–	–	1
Hypnaceae	–	–	–	–
**Acritodon nephophilus* H. Rob.	–	–	–	1
Campylophyllum sommerfeltii (Myrin) Hedenäs	–	–	–	1
Caribaeohypnum polypterum (Mitt.) Ando & Higuchi	–	–	–	1
Chryso-hypnum diminutivum (Hampe) W.R.Buck	–	–	1	1
Chryso-hypnum minutulum (Hedw.) W.R.Buck & H.A.Crum	–	–	–	1
Horridohypnum mexicanum (Thér.) W.R.Buck	–	–	–	1
Hypnum amabile (Mitt.) Hampe	–	–	–	1
Hypnum cupressiforme Hedw.	1	–	–	1
Mittenothamnium lehmannii (Besch.) Cardot	–	–	–	1
Mittenothamnium reptans (Hedw.) Cardot	–	–	–	1
Platygyriella densa (Hook.) W.R.Buck	–	1	–	1
Platygyriella pringlei (Cardot) W.R.Buck	–	1	–	1
Taxiphyllum deplanatum (Bruch & Schimp. ex Sull.) M.Fleisch.	–	–	–	1
Taxiphyllum taxirameum (Mitt.) M.Fleisch.	–	–	–	1
Vesicularia vesicularis (Schwägr.) Broth.	–	–	–	1

Appendix 1. — Continuation.

Families and species	HIDA	GUAN	VERA	OAXA
Lembophyllaceae	–	–	–	–
Pilotrichella flexilis (Hedw.) Ångstr.	–	–	–	1
Pilotrichella mauiensis (Sull.) A.Jaeger	–	–	–	1
Rigodium toxarion (Schwägr.) A.Jaeger	–	–	–	1
Leskeaceae	–	–	–	–
Haplocladium angustifolium (Hampe & Müll. Hal.) Broth.	–	–	–	1
Haplocladium microphyllum (Sw. ex Hedw.) Broth.	1	–	1	1
Leskeadelphus angustatus (Taylor) B.H.Allen	1	1	–	–
Lindbergia mexicana (Besch.) Cardot	1	–	–	–
Rozea andrieuxii (Müll. Hal.) Besch.	1	–	–	1
Leucobryaceae	–	–	–	–
Atractylocarpus flagellaceus (Müll. Hal.) R.S.Williams	–	–	–	1
Atractylocarpus longisetus (Hook.) E.B. Bartram	–	–	–	1
Atractylocarpus stenocarpus (Wilson) R.H.Zander	1	–	–	1
Bryohumbertia filifolia (Hornsch.) J.-P. Frahm	–	–	–	1
Campylopus albidovirens Herzog	–	–	–	1
Campylopus anderssonii (Müll. Hal.) A.Jaeger	–	–	–	1
Campylopus flexuosus (Hedw.) Brid.	–	–	–	1
Campylopus heterostachys (Hampe) A.Jaeger	–	–	–	1
Campylopus jamesonii (Hook.) A.Jaeger	–	–	–	1
Campylopus nivalis (Brid.) Brid.	1	–	–	1
Campylopus oblongus Thér.	–	–	–	1
Campylopus pilifer Brid.	1	1	–	1
Campylopus reflexisetus (Müll. Hal.) Broth.	–	–	–	1
Campylopus savannarum (Müll. Hal.) Mitt.	–	–	–	1
Campylopus schimperi Milde	1	–	–	1
Campylopus sharpii J.-P.Frahm, D.G. Horton & Vitt	–	–	–	1
Campylopus tallulensis Sull. & Lesq.	–	–	–	1
Campylopus zygodonticarpus (Müll. Hal.) Paris	–	–	–	1
Dicranodontium denudatum (Brid.) E.Britton	–	–	–	1
Dicranodontium pulchroalare Broth.	–	–	–	1
Leucobryum albidum (Brid. ex P. Beauv.) Lindb.	–	–	–	1
Leucobryum antillarum Schimp. ex Besch.	–	–	–	1
Leucobryum martianum (Hornsch.) Hampe ex Müll. Hal.	–	–	1	1
Pilopogon guadalupensis (Brid.) J.-P. Frahm	–	–	–	1
Leucodontaceae	–	–	–	–
Leucodon cryptotheca Hampe	1	–	–	–
Leucodon curvirostris Hampe	1	–	–	1
Leucomiaceae	–	–	–	–
Rhynchostegiopsis flexuosa (Sull.) Müll. Hal.	–	–	–	1
Rhynchostegiopsis tunguraguana (Mitt.) Broth.	–	–	–	1
Meteoriaceae	–	–	–	–
Meteoridium remotifolium (Müll. Hal.) Manuel	–	–	–	1
Meteorium illecebrum Sull.	1	–	–	1
Papillaria deppei (Hornsch. ex Müll. Hal.) A.Jaeger	–	–	–	1
Papillaria nigrescens (Sw. ex Hedw.) A.Jaeger	–	–	1	–
Toloxis imponderosa (Taylor) W.R.Buck	–	–	–	1
Trachypus viridulus (Mitt.) Broth.	–	–	–	1
Mniaceae	–	–	–	–
Epipterygium mexicanum (Besch.) Broth.	1	–	–	–
Mielichhoferia schiedeana Müll. Hal.	1	–	–	–
Mnium marginatum (Dicks.) P. Beauv.	1	–	–	1
Plagiomnium rhynchophorum (Harv.) T.J.Kop.	1	–	–	1
Plagiomnium rostratum (Müll. Hal.) Crosby	–	–	–	1
Pohlia cruda (Hedw.) Lindb.	1	–	–	–
Pohlia elongata Hedw.	–	–	–	1
Pohlia oerstediana (Müll. Hal.) A.J. Shaw	1	–	–	1
Pohlia papillosa (A.Jaeger) Broth.	–	–	–	1
Schizymenium schiedeanum (Müll. Hal.) A.J.Shaw	–	–	–	1
Neckeraceae	–	–	–	–
Homalia glabella (Hedw.) Schimp.	–	–	–	1
Homaliodendron flabellatum (Sm.) M.Fleisch.	–	–	–	1
Neckera chlorocaulis Müll. Hal.	1	–	–	1
Neckera ehrenbergii Müll. Hal.	1	–	–	1
Neckera urnigera Müll. Hal.	–	–	–	1
Porotrichodendron superbum (Taylor) Broth.	–	–	–	1
Porotrichum longirostre (Hook.) Mitt.	–	–	–	1
Porotrichum usagarum Mitt.	–	–	–	1
Octoblepharaceae	–	–	–	–
Octoblepharum albidum Hedw.	–	–	1	–

Appendix 1. — Continuation.

Families and species	HIDA	GUAN	VERA	OAXA
Orthodontiaceae	–	–	–	–
Orthodontium gracile (Wilson) Schwägr. ex Bruch & Schimp.	–	–	–	1
Orthostichellaceae	–	–	–	–
Orthostichella pentasticha (Brid.) W.R.Buck	–	–	1	–
Orthotrichaceae	–	–	–	–
Groutiella apiculata (Hook.) H.A.Crum & Steere	–	–	1	–
Groutiella tomentosa (Hornsch.) Wijk & Margad.	–	–	1	–
Macrocoma orthotrichoides (Raddi) Wijk & Margad.	–	–	–	1
Macrocoma tenuis (Hook. & Grev.) Vitt	1	–	–	1
Macromitrium cirrosum (Hedw.) Brid.	–	–	–	1
Macromitrium guatemalense Müll. Hal.	–	–	–	1
Macromitrium longifolium (Hook.) Brid.	–	–	–	1
Macromitrium sharpii H.A.Crum ex Vitt	–	–	–	1
Orthotrichum aequatoreum Mitt.	–	–	–	1
Orthotrichum bartramii R.S. Williams	–	–	–	1
Orthotrichum diaphanum Brid.	–	1	–	–
Orthotrichum hortoniae Vitt	–	–	–	1
Orthotrichum pycnophyllum Schimp.	1	–	–	1
Schlotheimia jamesonii (Arn.) Brid.	–	–	–	1
Schlotheimia rugifolia (Hook.) Schwägr.	–	–	1	1
Zygodon campylophyllus Müll. Hal.	1	–	–	1
Zygodon ehrenbergii Müll. Hal.	–	–	–	1
Zygodon liebmannii Schimp.	–	–	–	1
Zygodon obtusifolius Hook.	1	–	–	1
Zygodon reinwardtii (Hornsch.) A.Braun	–	–	–	1
Zygodon viridissimus (Dicks.) Brid.	1	–	–	1
Phyllogoniaceae	–	–	–	–
Phyllogonium fulgens (Hedw.) Brid.	–	–	–	1
Pilotrichaceae	–	–	–	–
Cyclodictyon albicans (Hedw.) Kuntze	–	–	–	1
Cyclodictyon erubescens E.B. Bartram	–	–	–	1
Cyclodictyon roridum (Hampe) Kuntze	–	–	–	1
Hypnella pilifera (Hook. f. & Wilson) A.Jaeger	–	–	–	1
Lepidopilum amplirete (Sull.) Mitt.	–	–	–	1
Lepidopilum scabrisetum (Schwägr.) Steere	–	–	–	1
Pilotrichum evanescens (Müll. Hal.) Crosby	–	–	–	1
Trachyxiphium guadalupense (Brid.) W.R.Buck	–	–	–	1
Trachyxiphium subfalcatum (Hampe) W.R.Buck	–	–	–	1
Plagiotheciaceae	–	–	–	–
Herzogiella cylindricarpa (Cardot) Z. Iwats.	–	–	–	1
Plagiothecium drepanophyllum Renauld & Cardot	–	–	–	1
Polytrichaceae	–	–	–	–
Atrichum androgynum (Müll. Hal.) A.Jaeger	–	–	–	1
Atrichum oerstedianum (Müll. Hal.) Mitt.	–	–	–	1
Oligotrichum aligerum Mitt.	–	–	–	1
Pogonatum campylocarpum (Müll. Hal.) Mitt.	–	1	–	1
Pogonatum comosum (Müll. Hal.) Mitt.	1	–	–	–
Pogonatum oligodus (Kunze ex Müll. Hal.) Mitt.	1	1	–	1
Pogonatum subflexuosum (Lorentz) Broth.	–	–	–	1
Pogonatum tortile (Sw.) Brid.	–	–	–	1
Polytrichastrum tenellum (Müll. Hal.) G.L. Sm.	–	–	–	1
Polytrichum commune Hedw.	–	–	–	1
Polytrichum juniperinum Hedw.	1	–	–	1
Pottiaceae	–	–	–	–
Aloina hamulus (Müll. Hal.) Broth.	1	–	–	–
Aloinella catenula Cardot	1	–	–	–
Anoectangium aestivum (Hedw.) Mitt.	1	–	–	1
Barbula arcuata Griff.	–	–	–	1
Barbula indica (Hook.) Spreng.	–	–	–	1
Barbula orizabensis Müll. Hal.	1	–	–	1
Bellibarbula recurva (Griff.) R.H.Zander	–	1	–	1
Bryoerythrophyllum campylocarpum (Müll. Hal.) H.A.Crum	–	–	–	1
Bryoerythrophyllum inaequalifolium (Taylor) R.H.Zander	1	–	–	1
Bryoerythrophyllum jamesonii (Taylor) H.A.Crum	1	–	–	1
Bryoerythrophyllum recurvirostrum (Hedw.) P.C. Chen	1	–	–	1
Chionoloma angustatum (Mitt.) M. Menzel	–	–	–	1
Didymodon australasiae (Hook. & Grev.) R.H.Zander	1	–	–	1
Didymodon ferrugineus (Schimp. ex Besch.) M.O.Hill	–	–	–	1
**Didymodon incrassatolimbatus* Cardot	1	–	–	1
Didymodon rigidulus Hedw.	1	1	–	1

Appendix 1. — Continuation.

Families and species	HIDA	GUAN	VERA	OAXA
Didymodon vinealis (Brid.) R.H.Zander	1	–	–	1
Globulinella globifera (Hampe) Steere	–	–	–	1
Hymenostylium recurvirostrum (Hedw.) Dixon	–	–	–	1
Hyophila involuta (Hook.) A.Jaeger	–	–	1	1
Leptodontium capituligerum Müll. Hal.	1	–	–	–
Leptodontium flexifolium (Dicks.) Hampe	1	–	–	1
Leptodontium pungens (Mitt.) Kindb.	–	–	–	1
Leptodontium viticulosoides (P. Beauv.) Wijk & Margad.	1	–	–	1
Mironia crassicuspis (H. Rob.) R.H.Zander	–	–	–	1
Molendoa sendtneriana (Bruch & Schimp.) Limpr.	–	–	–	1
Plaubelia sprengelii (Schwägr.) R.H.Zander	–	–	1	–
Pleuridium mexicanum Cardot	–	–	–	1
Pleuridium subulatum (Hedw.) Rabenh.	1	–	–	–
Pleurochaete squarrosa (Brid.) Lindb.	1	–	–	1
Pseudocrossidium replicatum (Taylor) R.H.Zander	1	–	–	1
Rhexophyllum subnigrum (Mitt.) Hilp.	1	1	–	–
Scopelophila ligulata (Spruce) Spruce	–	–	–	1
Splachnobryum obtusum (Brid.) Müll. Hal.	–	–	1	–
Streptopogon calymperes Müll. Hal.	–	–	–	1
Streptopogon erythrodontus (Taylor) Wilson	–	–	–	1
Syntrichia amphidiacea (Müll. Hal.) R.H.Zander	1	–	–	1
Syntrichia bogotensis (Hampe) Mitt. ex R.H.Zander	–	–	–	1
Syntrichia fragilis (Taylor) Ochyra	1	–	–	1
Syntrichia laevipila Brid.	–	1	–	–
Syntrichia obtusissima (Müll. Hal.) R.H.Zander	1	1	–	1
Timmiella anomala (Bruch & Schimp.) Limpr.	1	–	–	1
Tortella humilis (Hedw.) Jenn.	–	–	1	1
Tortella tortuosa (Schrad. ex Hedw.) Limpr.	–	–	–	1
Tortula quitoensis Taylor	1	–	–	–
Trichostomum brachydontium Bruch	1	–	–	1
Trichostomum crispulum Bruch	–	1	–	1
Trichostomum tenuirostre (Hook. & Taylor) Lindb.	1	–	–	1
Weisiopsis oblonga Thér.	–	–	–	1
Weissia condensa (Voit) Lindb.	–	–	–	1
Weissia controversa Hedw.	–	–	1	–
Weissia jamaicensis (Mitt.) Grout	–	–	–	1
Weissia ligulifolia (E.B. Bartram) Grout	–	1	–	–
Prionodontaceae	–	–	–	–
Prionodon densus (Sw. ex Hedw.) Müll. Hal.	1	–	–	1
Prionodon luteovirens (Taylor) Mitt.	–	–	–	1
Pterobryaceae	–	–	–	–
Pireella pycnothallodes (Müll. Hal.) M.Fleisch.	–	–	–	1
Pterobryopsis mexicana (Renauld & Cardot) M.Fleisch.	–	–	–	1
Renauldia mexicana (Mitt.) H.A.Crum	–	–	–	1
Ptychomitriaceae	–	–	–	–
Ptychomitrium lepidomitrium (Müll. Hal.) Schimp.	1	–	–	1
Ptychomitrium serratum Bruch & Schimp.	–	–	–	1
Pylaisiaceae	–	–	–	–
Homomallium mexicanum Cardot	–	1	–	–
**Homomallium sharpii* Ando & Higuchi	–	–	–	1
Pylaisia falcata Schimp.	1	–	–	1
Pylaisia polyantha (Hedw.) Schimp.	–	–	–	1
Pylaisia selwynii Kindb.	–	–	–	1
Pylaisiadelphaceae	–	–	–	–
Aptychella proligera (Broth.) Herzog	–	–	–	1
Heterophyllium affine (Hook.) M.Fleisch.	–	–	–	1
Isopterygium tenerum (Sw.) Mitt.	–	–	1	1
Platygyrium fuscoluteum Cardot	–	–	–	1
Pylaisiadelpha tenuirostris (Bruch & Schimp. ex Sull.) W.R.Buck	–	–	–	1
Taxithelium planum (Brid.) Mitt.	–	–	1	–
Wijkia costaricensis (Dixon & E.B. Bartram) H.A.Crum	–	–	–	1
Racopilaceae	–	–	–	–
Racopilum tomentosum (Hedw.) Brid.	1	–	1	1
Rhabdoweisiaceae	–	–	–	–
Amphidium tortuosum (Hornsch.) Cufod.	–	–	–	1
Rhabdoweisia fugax (Hedw.) Bruch & Schimp.	1	–	–	1
Symblepharis vaginata (Hook. ex Harv.) Wijk & Margad.	1	–	–	1
Rhachitheciaceae	–	–	–	–
Rhachithecium perpusillum (Thwaites & Mitt.) Broth.	–	–	–	1
Rhacocarpaceae	–	–	–	–
Rhacocarpus purpurascens (Brid.) Paris	–	–	–	1

Appendix 1. — Continuation.

Families and species	HIDA	GUAN	VERA	OAXA
Rhizogoniaceae	–	–	–	–
Pyrrhobryum spiniforme (Hedw.) Mitt.	–	–	–	1
Sematophyllaceae	–	–	–	–
Acroporium longirostre (Brid.) W.R.Buck	1	–	–	1
Acroporium pungens (Hedw.) Broth.	–	–	–	1
Sematophyllum adnatum (Michx.) E.Britton	–	–	1	1
Sematophyllum cuspidiferum Mitt.	–	–	–	1
Sematophyllum galipense (Müll. Hal.) Mitt.	–	–	1	–
Sematophyllum marylandicum (A.Jaeger) E.Britton	–	–	–	1
Sematophyllum subpinnatum (Brid.) E.Britton	–	–	1	1
Sematophyllum swartzii (Schwägr.) W.H. Welch & H.A.Crum	–	–	–	1
Sphagnaceae	–	–	–	–
Sphagnum limbatum Mitt.	–	–	–	1
Sphagnum meridense (Hampe) Müll. Hal.	–	–	–	1
Sphagnum sparsum Hampe	–	–	–	1
Sphagnum tenellum (Brid.) Bory	–	–	–	1
Splachnaceae	–	–	–	–
Brachymitrion cochabambae (Müll. Hal.) A.K. Kop.	–	–	–	1
Brachymitrion jamesonii Taylor	–	–	–	1
Tayloria chiapensis H.A.Crum	–	–	–	1
Stereophyllaceae	–	–	–	–
Entodontopsis leucostega (Brid.) W.R.Buck & Ireland	–	–	1	–
Stereophyllum radiculosum (Hook.) Mitt.	–	–	1	–
Thuidiaceae	–	–	–	–
Cyrto-hypnum minutulum (Hedw.) W.R.Buck & H.A.Crum	–	–	–	1
Cyrto-hypnum schistocalyx (Müll. Hal.) W.R.Buck & H.A.Crum	–	–	–	1
Cyrto-hypnum sharpii (H.A.Crum) W.R.Buck & H.A.Crum	–	–	–	1
Rauiella lagoensis (Hampe) W.R.Buck	–	–	–	1
Thuidium delicatulum (Hedw.) Schimp.	1	–	–	1
Thuidium tamariscinum (Hedw.) Schimp.	–	–	1	–
Thuidium tomentosum Schimp.	–	–	1	1
Timmiellaceae	–	–	–	–
Luisierella barbula (Schwägr.) Steere	–	–	1	–
Total	93	23	57	339