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Filling the knowledge gaps: corticolous lichen diversity in the Ecuadorian Amazon

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ABSTRACT

While lichens are vital for ecosystem processes and serve as useful bioindicators, lichen diversity remains understudied, particularly in southern Ecuador. Here, we report the first inventory of corticolous (on tree bark) lichens in the Pachicutza watershed, Zamora-Chinchipe, Ecuador, in the Amazonian region. We conducted a random survey across the understory of the forest, without predefined sampling units (40 trees were sampled within a 2500 m² area). A total of 30 lichen species from 19 families were recorded, with the most frequent species in the Parmeliaceae and Roccellaceae. Additional noteworthy species were identified in the Graphidaceae, Trypetheliaceae, and Pyrenulaceae. This small sampling revealed a diversity of lichens in the Pachicutza watershed, which should be protected as a reservoir of biodiversity. Although the area is currently well-preserved, the increasing pressures of mining and deforestation in the region underscore the need for monitoring ecological integrity. Future research should explore new molecular approaches for characterizing lichen diversity, which have implications for assessing the impact of anthropogenic activities on these ecosystems.

KEYWORDS: Amazonian Forest, bioindicators, Crustose lichens, Graphidaceae, lichenized fungi, Parmeliaceae

Llenando las lagunas de conocimiento: diversidad de líquenes corticícolas en la Amazonía ecuatoriana

RESUMEN

Aunque los líquenes son esenciales para los procesos ecosistémicos y actúan como bioindicadores útiles, su diversidad sigue siendo poco estudiada, especialmente en el sur de Ecuador. En este trabajo, presentamos el primer inventario de líquenes cortícolas (sobre corteza de árboles) en la microcuenca de Pachicutza, Zamora-Chinchipe, Amazonía ecuatoriana. Realizamos un muestreo aleatorio en el sotobosque del bosque sin unidades de muestreo predefinidas (se muestrearon 40 árboles en 2500 m²). Se registraron un total de 30 especies de líquenes pertenecientes a 19 familias, siendo las especies más frecuentes de Parmeliaceae y Roccellaceae. También se identificaron especies destacadas de Graphidaceae, Trypetheliaceae y Pyrenulaceae. Este muestreo reducido reveló una alta diversidad de líquenes en la microcuenca de Pachicutza, la cual debería ser protegida como un reservorio de biodiversidad. Aunque el área se encuentra actualmente bien conservada, las crecientes presiones por minería y deforestación en la región subrayan la necesidad de monitorear su integridad ecológica. Investigaciones futuras deberían explorar nuevos enfoques moleculares para caracterizar la diversidad de líquenes, lo que tendría implicaciones para evaluar el impacto de las actividades antropogénicas en estos ecosistemas.

PALABRAS CLAVE: Bosques amazónicos, diversidad Neotropical, Graphidaceae, hongos liquenizados, líquenes crustosos, Parmeliaceae

Symbiotic lichens (fungi and algae or cyanobacteria, Hawksworth 2021) can thrive in a variety of habitats, from deserts to tropical forests, where they contribute to nutrient cycling and can be bioindicators of anthropic impacts (Lücking *et al.* 2017). Despite their potential ecological importance, lichens in the Ecuadorian Amazon remain poorly studied (Lücking and Matzer 2001). Global estimates exceed 20,000 species (Lücking *et al.* 2017), and at the country level, Ecuador has at least 2,599 species, primarily reported from non-Amazonian regions (Yánez-Ayabaca *et al.* 2023). Lichens are most diverse in tropical forests, where microhabitat variability fosters richness (Lumbsch *et al.* 2011). Sensitive genera, such as *Lobariella* and *Usnea,* serve as bioindicators due to their vulnerability to pollutants and environmental changes

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(Estrada and Nájera 2011). Human activities, including deforestation and mining, pose a threat to Amazonian lichen communities (Ellis *et al.* 2021).

Because lichens are, in general, understudied, we examine corticolous lichen diversity in another southern Ecuadorian Amazon location: the Pachicutza watershed, El Pangui, Zamora-Chinchipe. Our goal was to estimate the richness of the lichen species and describe the diversity and growth forms of these species. The Pachicutza watershed (3°40’02.1”S, 78°37’22.7”W; Figure 1) was selected because it is minimally disturbed and ecologically significant as a water source. Pachicutza vegetation is characterized as subtropical humid forests with an annual average temperature of 21–24°C and a relative humidity exceeding 80% (GAD El Pangui 2020). High humidity and cloud cover support epiphytic lichens, particularly crustose and foliose forms (Lakatos *et al.* 2006, Kelly *et al.* 2004). Also, lichen diversity is a response to the unique plant composition that arises from climate, geology, and human activities (Fernández-Prado *et al.* 2023).

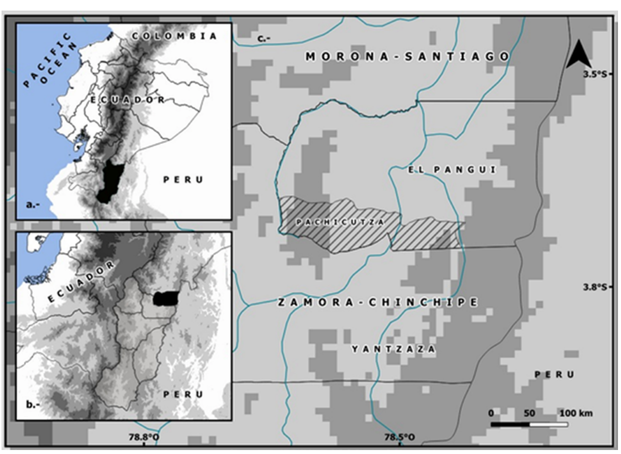

Figure 1. Location of the study area. (a) The location of Zamora Chinchipe Province in southern Ecuador, South America. (b) Zoomed-in view of the province, showing the El Pangui Canton. (c) Detailed map showing the Pachicutza watershed.

Sampling focused on old-growth forests with trees dominated by families Lauraceae, Melastomataceae, and Fabaceae. It is known that crustose species are more abundant in shade, while foliose species are found in canopy gaps (Kelly *et al.* 2004; Van Leerdam *et al.* 1990). Samples (N = 116) were collected using sterile tools and placed in labeled paper bags to avoid contamination (Déleg *et al.* 2021). Identification was in the laboratory using traditional microscopy and chemical spot tests, such as potassium hydroxide (KOH), sodium hypochlorite (NaClO), and Lugol’s iodine (I_3K, Orange *et al.* 2010). All specimens were deposited in the Herbarium of the Universidad Técnica Particular de Loja (HUTPL), under lot number M. Vega 003 (HUTPL: Prov. Zamora Chinchipe, Cantón el Pangui, Parroquia Pachicutza, Localidad, 03°40′02.1”S, 78°37′22.7”W, 842 m a.s.l. 8 de abril 2024). At the time of submission, specimens remain uncatalogued, but their deposition is confirmed by the herbarium curator (Á. Benítez, co-author).

We found a total of 30 lichen species in 19 families (Table 1, Figures 2 and 3). Parmeliaceae and Roccellaceae were the most diverse families (n = 3 species). Some frequently recorded genera, including *Herpothallon*, *Cryptothecia*, *Leptogium*, *Usnea*, and *Cladonia*, are often found in montane forests in both temperate and tropical regions (Martínez 2019; Etayo 2017).

Table 1. Corticolous lichen species recorded in the Pachicutza watershed, southeastern Ecuadorian Amazon. Each species is classified by its predominant growth form: Crustose (Cr), Filamentous (Fi), Fruticose (Fr), Foliose (Fo), or Gelatinous (Ge). The “Frequency” column indicates the absolute number of occurrences recorded per species across all sampled trees. Sampling was conducted randomly across the forest understory, without predefined plots or a fixed number of trees.

Species	Growth habit	Frequency
Arthoniaceae		
Cryptothecia sp.	Cr	5
Herpothallon rubrocinctum (Ehrenb. Fr.) G. Thor	Cr	6
Candelariaceae		
Candelaria concolor (Dicks.) Stein	Fo	3
Chrysotrichaceae		
Chrysothrix xanthina (Vain.) Kalb	Cr	8
Coccocarpiaceae		
Coccocarpia palmicola (Spreng.) Arv. and D. J. Galloway	Fo	5
Coccocarpia pellita (Ach.) Müll. Arg.	Fo	4
Cladoniaceae		
Cladonia chlorphaea (Flörke ex Sommerf.) Spreng.	Fr	6
Coenogoniaceae		
Coenogonium linkii Ehrenb.	Fi	3
Collemataceae		
Leptogium phyllocarpum (Pers.) Mont.	Fo	3
Leptogium sp.	Fo	4
Graphidaceae		
Graphis chrysocarpa (Raddi) Spreng	Cr	2
Graphis sp.	Cr	1
Hygrophoraceae		
Cora glabrata (Spreng.) Fr.	Fo	7
Dictyonema thelephora (Spreng.) Zahlbr.	Fi	4
Lobariaceae		
Lobariella pallida (Hook) B. Moncada & Lücking	Fo	5
Megalosporaceae		
Megalospora tuberculosa (Fée) Sipman	Cr	2
Parmeliaceae		
Flavoparmelia sp.	Fo	3
Parmotrema sp.	Fo	8
Usnea laevis (Eschw.) Nyl.	Fr	10

Table 1. Continued

Species	Growth habit	Frequency
Peltigeraceae		
Crocodia aurata (Ach.) Link.	Fo	5
Peltigeria austroamericana Zahlbr	Fo	3
Pertusariaceae		
Pertusaria sp.	Cr	3
Physciaceae		
Heterodermia aff. *spathulifera* Moberg and Purvis	Fo	2
Phaeophyscia orbicularis (Neck.) Moberg	Fo	3
Pyrenulaceae		
Pyrenula sp.	Cr	2
Roccellaceae		
Bactrospora denticulada (Vain.) Egea and Torrente	Cr	4
Bactrospora sp.	Cr	1
Dichosporidium nigrocinctum (Ehrenb.) G.Thor	Cr	2
Teloschistaceae		
Caloplaca crocea (Kremp.) Hafellner and Poelt	Cr	1
Trypetheliaceae		
Pseudopyrenula sp.	Cr	1

Figure 2. Diversity of lichen and growth forms recorded in the Pachicutza watershed: **A.** *Bactrospora denticulada*, **B.** *Bactrospora* sp., **C.** *Caloplaca crocea*, **D.** *Candelaria concolor*, **E.** *Chrysothrix xanthina*, **F.** *Cladonia chlorphaea*, **G.** *Coccocarpia palmicola*, **H.** *Coccocarpia pellita*, **I.** *Coenogonium linkii*, **J.** *Cora glabrata*, **K.** *Crocodia aurata*, **L.** *Cryptothecia* sp., **M.** *Dichosporidium nigrocinctum*, **N.** *Dictyonema thelephora*, **O.** *Flavoparmelia* sp. The scale corresponds to 10 mm.

Figure 3. Diversity of lichen and growth forms recorded in the Pachicutza watershed: **A.** *Graphis chrysocarpa*, **B.** Graphis sp. **C.** *Herpothallon rubrocinctum*, **D.** *Heterodermia* aff. *spathulifera*, **E.** *Leptogium phyllocarpum*, **F.** *Leptogium* sp. **G.** *Lobariella pallida*, **H.** *Megalospora tuberculosa*, **I.** *Parmotrema* sp. **J.** *Peltigeria austroamericana*, **K.** *Pertusaria* sp. **L.** *Phaeophyscia orbicularis*, **M.** *Pseudopyrenula* sp. **N.** *Pyrenula* sp. **O.** *Usnea* sp. The scale corresponds to 10 mm.

Foliose lichens—those with flattened, leaf-like thalli (20% of the species) were primarily found at mid-height in the understory where humidity is higher (Van Leerdam *et al.* 1990; Benítez *et al.* 2018; Fernández-Prado *et al.* 2023). Fruticose lichens, characterized by their branched and often bushy structures, tended to be associated with older trees that provide more stable microhabitats. Gelatinous (*Leptogium* spp.) and filamentous lichens (*Dictyonema* spp. and *Coenogonium* spp.) were rare but ecologically significant, as their presence reflects microhabitats with consistently high humidity, typically associated with well-preserved forest understories (Déleg *et al.* 2021). Crustose lichens dominated the community, comprising 63% of the species, which is typical in tropical understories (Plata and Lücking 2013; Déleg *et al.* 2021). These lichens, including *Herpothallon* spp. and *Cryptothecia* spp. are abundant in shade and humid conditions (Benítez *et al.* 2018), and are common in Amazonian forests (Déleg *et al.* 2021). Fruticose lichens

(13%) were less abundant than foliose and crustose lichens because these species tend to be associated with higher light availability and lower humidity (Benítez *et al.* 2018).

The Parmeliaceae and Roccellaceae (both with 3 species) were the richest families, reflecting their ecological adaptability and dominance in humid forests (Nadkarni *et al.* 2013; Bungartz *et al.* 2010). Crustose lichens are typically early colonizers, and so when found, they suggest recent disturbance, while fruticose and foliose forms indicate more stable microhabitats. Sensitive genera such as *Usnea* (1 species, 10 records) and *Lobariella* (1 species, 5 records) are valuable bioindicators of air quality and forest integrity, supporting the view that this study area is well-preserved (Estrada and Nájera 2011; Plata and Lücking 2013). Species such as *Usnea laevis* (Eschw.) Nyl. and certain representatives of the Graphidaceae are not indicators of entire ecosystems, but they can reflect localized anthropogenic disturbances, such as deforestation and habitat degradation associated with human activities, including mining, road construction, or agricultural expansion (Moncada and Lücking 2021).

The 30 species recorded in this study may seem modest in absolute terms, but species richness is known to vary substantially across Neotropical forests depending on sampling scale, effort, and forest structure. Large-scale surveys have reported 307 species from 240 trees in southern Ecuador (Benítez *et al.* 2015), 131 species from 300 trees in Brazil (Käffer *et al.* 2011), and 135 species from 112 trees in Colombia (España-Puccini *et al.* 2024). In contrast, our results are comparable to those of similar-scale studies, such as the 47 species recorded from 20 trees in Panama (Vissuetti *et al.* 2025) or the 65 species from 120 trees in southeastern Ecuador (Ganazhapa-Plasencia *et al.* 2025). These differences highlight the impact of sampling design on lichen inventories and underscore the importance of small-scale assessments in underexplored Amazonian areas.

The corticolous lichen community in the Pachicutza forests exhibits moderate but ecologically representative diversity, shaped by the structural complexity of the forest. The range of microhabitats, varying in light, humidity, and bark texture, supports multiple lichen growth forms, each associated with specific environmental conditions. In particular, the presence of both foliose and fruticose lichens suggests a relatively stable microclimate and well-preserved canopy structure, which are key features of mature Amazonian forests.

Pachicutza forests are under increasing threat from deforestation and mining activities, especially gold mining (Mestanza-Ramón *et al.* 2022). Gold mining degrades and destroys habitats, causing air pollution that negatively impacts lichens. Mining runoff also affects water quality, and consequently, gold mining poses a threat to nearby lichen communities (Fernández-Prado *et al.* 2023).

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