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# Preliminary Record of Mangrove Lichens in Davao City, Philippines

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A B S T R A C T

This study offers the first documentation of mangrove species in Davao City, addressing the biodiversity paradox of uncharted Philippine mangrove lichens. Ninety mature trees from Matina, Panacan, and Lasang were sampled in September and October of 2025 to assess mangrove lichen diversity. A total of 31 species from 12 families were identified using morphoanatomical analysis and chemical spot testing. While the disturbed Lasang site showed habitat homogeneity dominated by stress-tolerant dust lichens, Matina served as a biodiversity reservoir for *Graphis* species. These results provide crucial biogeographic baseline data, as the majority of species still lack IUCN data. The findings highlight the need to protect urban mangroves as vital habitats for distinctive epiphytic communities amid growing coastal development.

## INTRODUCTION

Mangrove forests, which are part of the "blue carbon" ecosystems, play an important role in regulating atmospheric and oceanic carbon. Mangrove forests are critical coastal ecosystems that support a variety of life forms, provide significant shoreline protection, and play a role in carbon sequestration. This consists of highly specialized mangrove trees that harbor a variety of epiphytes. Epiphytes such as manglicolous lichens, also referred to as mangrove lichens, are a very small but essential component of these forests. These mutualisms are maintained through the algal-symbiotic fungus interaction, which is found on the bark of the mangrove tree and prospers in adverse conditions such as high salinity, irregular tides, and high sunlight exposure (Tatipamula et al., 2021; Ismail et al., 2024). Unfortunately, very little research has been conducted on these specialized epiphytes, despite the species' importance as bioindicators.

Globally, very little is known about mangrove lichens, their taxonomy, and their function in nature. The distinctive vegetation of mangrove coastal forests has received very little attention in lichenology, which is often conducted in terrestrial or temperate biomes. As a result, the Philippines is currently facing the "biodiversity paradox," characterized by an extremely high number of species. Therefore, there is a lack of research, particularly given its status as a biodiversity hotspot and its mangrove diversity (Berba & Matias, 2022).

As cited in a study in the Philippines, only 40 species of lichen are found in mangrove forests in the Calabarzon region, and 29 of these were first described (Lucban & Paguirigan, 2019). Additionally, another study reported that of the eight mangrove lichen species recorded in investigations in the province of Pangasinan, two were newly documented in the Philippines (Fajardo & Bawingan, 2019). These related studies imply that there is a unique but unknown lichen flora in the mangrove forests of the Philippines, especially in Davao City, the largest city in the country by land area; thus, new records may come from these unexplored areas. Therefore, conducting this study generates regional biodiversity data to understand better the ecological role of lichens, which could be significant for environmental planning and future conservation activities.

## THEORETICAL REVIEW

### *Linnean Shortfall*

This theoretical framework serves as the anchor of this study, explaining the discrepancy between the number of species on Earth and those reported (Brown & Lomolino, 1998; Whittaker et al., 2005). Using the Biodiversity Inventory framework (Costello et al., 2015), the study highlights the necessity of comprehensive taxonomic documenting for successful ecological conservation. Patiño et al. (2014), who contend that high-intensity surveys in particular micro-habitats, such as mangrove forests, are the best way to reveal hidden species like lichens, support this strategy. Additionally, Das et al. (2021) agree that focused tropical inventories regularly produce new scientific records, supporting the application of a linear conceptual framework to close knowledge gaps in neglected areas such as Mindanao (Hortal et al., 2015).

On the other hand, several academics contest the adequacy of this conventional inventory-based theory. According to Mora et al. (2011), high-throughput DNA methods are preferred because the Linnean Shortfall is expanding so quickly that conventional taxonomic recording cannot keep up with extinction rates. Furthermore, Ladle and Hortal (2013) contend that a purely taxonomic goal may ignore the spatial dynamics required for true conservation, arguing that addressing the Linnean Shortfall alone is insufficient without addressing the Wallacean Shortfall (the lack of knowledge regarding geographical distribution). Because specialized niches in biodiversity hotspots are frequently the last frontiers for primary species discovery, the study's focus on manglicolous lichens in Davao City is conceptually sound despite these criticisms (Scheffers et al., 2012).

## METHODOLOGY

### *Research design*

The quantitative ecological inventory method was employed in this study to document and assess the species present and the alpha taxonomy of mangrove lichens. The study aimed to develop baseline data on species richness, abundance, and floristic composition in the selected mangrove ecosystems using the biodiversity assessment framework (Magurran, 2004).

### *Study area and sampling sites*

The survey was conducted in September and October 2025 in Davao City, Philippines, during low tide. There were three mangrove sites identified to have substantial mangrove coverage by the Department of Environment and Natural Resources Region XI. These mangrove forests vary in the extent of human influence and conservation efforts. The first site is the Aboitiz Cleanergy Park in Matina Aplaya (7° 01′ 41.28″ N, 125° 34′ 31.99″ E), which is an eight-hectare urban Marine Protected Area (MPA). The second site in Purok 18-A Pax, Barangay Panacan (7° 09′ 24.84″ N, 125° 39′ 24.84″ E), is described as a fragmented and stressed regrowth area due to intense industrialization. Lastly, the third site, Sitio Tambongon, Barangay Lasang (7° 15′ 27″ N, 125° 39′ 51″ E), managed by the Tambongon Fisherfolks Association (TAMFIAS), was a recovering site with the establishment of functioning nurseries.

### *Sampling and Taxonomic Identification*

Thirty mature mangrove trees per site were opportunistically selected using uniform criteria (>10 m spacing) to reduce bias and spatial autocorrelation (Reynolds et al., 2017; Neyens et al., 2019). Non-invasive methods were used to gather lichens (Nayaka, 2014), which were then air-dried for 48–72 hours before being prepared for morpho-anatomical and chemical analysis (Fajardo & Bawingan, 2019).

Stereomicroscopy (40×–400×) and common chemical spot tests (K, C, P, I) were used to identify the species (Fajardo & Bawingan, 2019; Joshi et al., 2018).

The published literature by Awasthi (1991), Ekman (2001), Lee and Hur (2022), Lücking and Archer (2009), and Santos et al. (2023) was used as keys for taxonomic verification. The IUCN Red List (2024) and the IUCN SSC Lichen Specialist Group (2024) were used to determine the conservation status.

*Data Analysis*

Paleontological Statistics (PAST) version 5.1 software was used to characterize the lichen community structure at each of the three study sites (Hammer et al., 2001). Three main indices were used to quantify alpha diversity: the Shannon-Wiener Index (H') to account for both species richness and abundance; Margalef's Richness Index ($D_{mg}$) to evaluate the number of species in relation to the total number of individuals; and Pielou's Evenness Index (J') to assess the equity of species distribution within each site (Magurran, 2004). In order to compare lichen assemblages in different mangrove settings, these measures offered a descriptive baseline.

*Ethics Statement*

Research was conducted under the Department of Environment and Natural Resources (DENR) Region XI gratuitous permit and approved ethics clearance by the Davao Oriental State University Research Ethics Board.

**RESULTS**

In the mangrove environments of Matina, Panacan, and Lasang in Davao City, 31 different lichen taxa have been identified. These taxa are found in 12 families and 19 genera. Arthoniaceae, Candelariaceae, Caliciaceae, Chrysothricaceae, Graphidaceae, Lecanoraceae, Opegraphaceae, Pertusariaceae, Physciaceae, Pyrenulaceae, Ramalinaceae, and Stereocaulaceae are among the families identified. Graphidaceae, which includes the genera *Allographa, Diorygma, Graphis*, and *Phaeographis,* was the most taxonomically diverse of them. *Arthothelium* and *Cryptothecia* under Arthoniaceae; *Candelariella* under Candelariaceae; *Dirinaria* and *Pyxine* under Caliciaceae; *Chrysothrix* under Chrysothricaceae; *Lecanora* under Lecanoraceae; *Opegrapha* under Opegraphaceae; *Lepra* and *Pertusaria* under Pertusariaceae; *Heterodermia* under Physciaceae; *Pyrenula* under Pyrenulaceae; *Bacidia* and *Biatora* under Ramalinaceae; and *Lepraria* under Stereocaulaceae.

*Taxonomic Enumeration*

**Family Arthoniaceae**

1. ***Arthothelium* sp.**

**Growth Form**: Crustose. **Taxonomic Notes**: The observed specimen was very small with a crustose thallus lacking clear features; however, spores were developing. The genus is characterized by immarginate, often star-shaped or irregular ascomata. The asci are bitunicate (globose to clavate) and contain hyaline, muriform ascospores**. Mangrove Host:** *Aegiceras floridum, Bruguiera cylindrica, Ceriops Tagal.* **Reference:** Kantvilas (2021)

2. ***Cryptothecia* sp. 1**

**Growth Form:** Crustose. **Taxonomic Notes**: Thallus byssoid and whitish, containing *Trentepohlia* photobiont. Medulla reacts I+ blue-black; spot tests K+ yellow, C-. The specimen is sterile/young, lacking organized ascocarps. The asci are spherical (fissitunicate) and embedded directly in soft, sterile thalline tissue. **Mangrove Host**: *Sonneratia alba*. **Reference:** Ram and Sinha (2016)

3. ***Cryptothecia* sp. 2**

**Growth Form**: Crustose. **Taxonomic Notes**: Thallus creamy color and smooth (C-, K-). Photobiont *Trentepohlia*. Asci were observed immersed without spores. This species is differentiated from *Lepraria* by the presence of *Trentepohlia* and immersed, sac-like asci within the thallus. **Mangrove Host:** *Excoecaria agallocha, Sonneratia alba*, *Bruguiera gymnorrhiza*. **Reference**: Ram and Sinha (2016)

**Family Candelariaceae**

4. ***Candelariella* sp.**

**Growth Form**: Crustose. **Taxonomic Notes:** Thallus egg-yellow to orange-yellow (K- reaction) containing candelariin/pulvic acid derivatives. Apothecia are lecanorine with concolorous discs; spores are simple to 1-septate with consistently polysporous asci. **Mangrove Host:** *Rhizophora apiculate, Bruguiera gymnorrhiza, Rhizophora mucronata*. **Reference:** Westberg (2005)

**Family Caliciaceae**

5. ***Dirinaria* cf. *minuta***

**Growth Form:** Foliose. **Taxonomic Notes:** Diminutive species; upper surface gray-white with maculae; lower cortex black, rhizines sparse/absent. No propagules or apothecia observed. P+ yellow cortex indicates atranorin. **Mangrove Host:** *Bruguiera cylindrica, Ceriops tagal*, *Rhizophora mucronata*. **Reference:** Awasthi (1975)

6. ***Pyxine* sp. 1**

**Growth Form:** Foliose. **Taxonomic Notes:** Thallus greenish, lobes 0.5–0.9 mm; with patches of pruina. UV- reaction. **Mangrove Host:** *Sonneratia alba*. **Reference:** Rogers (1986)

7. ***Pyxine* sp. 2**

**Growth Form:** Foliose. **Taxonomic Notes**: Thallus whitish, shiny; lobes linear (0.1–0.2 mm), truncate. Pustules/pseudocyphellae present. Rhizinate. UV-. Distinguished by narrow, linear lobes and marginal pseudocyphellae. **Mangrove Host**: *Rhizophora mucronata*. **Reference:** Rogers (1986)

**Family Chrysothricaceae**

8. ***Chrysothrix xanthina* (Vain.) Kalb**

**Growth Form:** Crustose. **Taxonomic Notes**: Young specimens observed. The thallus is leprose, bright yellow-orange, and entirely sorediate/granulose, lacking a cortex. Chemistry typically includes pinastric acid (K-, UV+ orange). **IUCN Red List Classification:** Least Concern (LC): Widespread and abundant**.** **Mangrove Host:** *Avicennia lanata*, *Sonneratia alba, Rhizophora apiculata*. **Reference**: Kalb (2001)

**Family Graphidaceae**

**9.** ***Allographa fujianensis*** **(Z.F. Jia & J.C. Wei) Lücking & Kalb**

**Growth Form:** Crustose. **Taxonomic Notes:** Diagnosed by lirellae showing a completely carbonized exciple and muriform, hyaline ascospores (Figure 2). **IUCN Red List Classification**: Data Deficient (DD): Insufficient data to assess risk/Not Evaluated (NE): Not yet assessed. **Mangrove Host:** *Bruguiera cylindrica, Sonneratia alba, Ceriops tagal*. **References:** Jia and Wei (2008); Lücking and Kalb (2018)


**Figure 1. Morphological and Anatomical Characteristics of *Allographa fujianensis*.**

(a) Macroscopic surface view: The specimen shows a crustose thallus with prominent, black, elongated lirellae. The lirellae are relatively thick and often branched or curved. The black-and-white scale on the left provides a reference of 1 mm per major division. (b) Apothecial cross-section: A transverse section of a lirelline apothecium demonstrating complete carbonization. The excipulum (the protective outer layer) is entirely blackened, surrounding the pale hymenium. The ocular micrometer scale at the bottom provides a reference for the internal tissue dimensions. (c) Spore morphology: High-magnification view of muriform spores. The spores are heavily pigmented (melanized) and display a complex grid of both horizontal and vertical septa. Using an ocular micrometer, these spores measure approximately 25–35 µm in length.

**10.** ***Diorygma pruinosum*** **(Eschw.) Kalb, Staiger & Elix**

**Growth Form:** Crustose. **Taxonomic Notes:** Thallus features non-carbonized, "glaucinum-type" lirelline apothecia with abundant white pruina. Cross-section reveals large muriform spores and an I+ violet hymenium. **IUCN Red List Classification:** Least Concern (LC): Widespread and abundant. **Mangrove Host:** *Bruguiera cylindrica, Rhizophora stylosa, Ceriops tagal*. **Reference:** Kalb et al. (2004)

**11.** ***Graphis*** **cf.** ***kelungana.***

**Growth Form:** Crustose. **Taxonomic Notes:** Lirellae are emergent with a lateral thalline margin; labia are entire (not striate). The exciple is laterally carbonized. Spores are transversely septate and hyaline. **Mangrove Host:** *Bruguiera cylindrica, Rhizophora stylosa*. **Reference:** Lücking et al. (2009)

**12.** ***Graphis cincta*** **(Pers.) Aptroot**

**Growth Form:** Crustose. **Taxonomic Notes**: Lirellae display lateral margins with non-pruinose labia. The hymenium is inspersed (oil droplets). Diagnostic features include a pale, uncarbonized to laterally carbonized exciple and the presence of norstictic acid (K+ yellow-red) (Figure 3). **IUCN Red List Classification**: Data Deficient (DD): Insufficient data to assess risk. **Mangrove Host:** *Sonneratia caseolaris*. **References**: Lücking et al. (2009); Aptroot (2002)

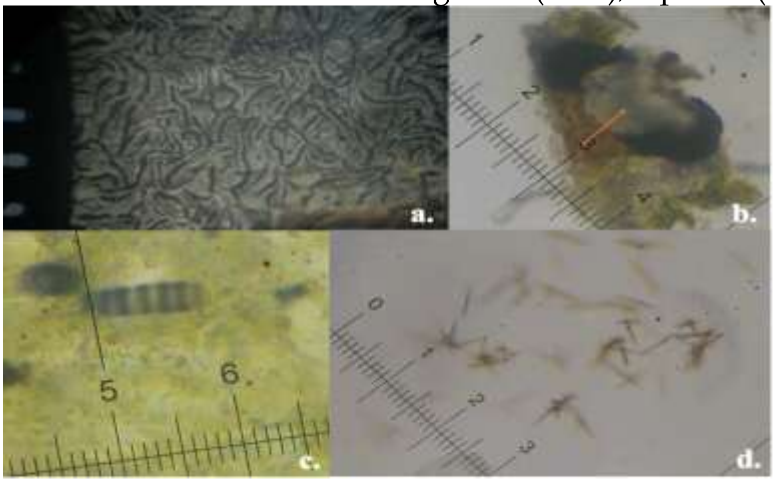


**Figure 2. Morphological, Anatomical, and Chemical Characteristics of *Graphis cincta*.**

(a) Macroscopic surface view: The thallus features elongated fruiting bodies (lirellae) with distinct lateral margins. Note that the labia (the "lips" of the lirellae) are non-pruinose (smooth and black, lacking a powdery coating). The black-and-white scale on the left indicates 1 mm per major division. (b) Apothecial cross-section: A transverse section of a lirelline apothecium. The orange arrow points to the inspersed hymenium, which is filled with tiny oil droplets, giving it a cloudy appearance. The dark edges of the structure show lateral carbonization (blackened fungal tissue). (c) Spore morphology: A high-magnification view of a transversely septate spore. Unlike the muriform spores seen in other species, this spore only has horizontal walls. Using an ocular micrometer, this spore measures approximately 30–35 µm in length. (d) Chemical test (K reaction): Microscopic view of the chemical reaction with Potassium hydroxide (K). The change from yellow to red and the formation of needle-like (acicular) crystals confirm the presence of norstictic acid.

**13. *Graphis immersicans* A.W. Archer.**

**Growth Form:** Crustose. **Taxonomic Notes:** Lirellae are immersed; the exciple is carbonized apically or laterally. Spores are small and transversely septate. **IUCN Red List Classification:** Data Deficient (DD): Insufficient data to assess risk. **Mangrove Host:** *Bruguiera cylindrica, Rhizophora stylosa*. **Reference:** Lücking et al. (2009)

**14. *Graphis modesta* Zahlbr.**

**Growth Form:** Crustose. **Taxonomic Notes:** Thallus whitish and pruinose. Lirellae are immersed to erumpent with entire, often pruinose labia. The excipulum is laterally carbonized; spores are transversely septate (Figure 4). **IUCN Red List Classification:** Data Deficient (DD): Insufficient data to assess risk. **Mangrove Host:** *Bruguiera cylindrica, Rhizophora stylosa*, *Rhizophora mucronata*. **Reference:** Lücking et al. (2009)

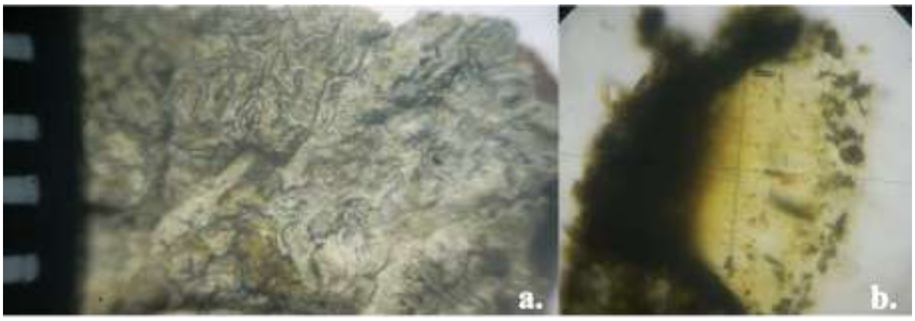

**Figure 3. Morphological and Anatomical Characteristics of *Graphis modesta*.**

(a) Macroscopic surface view: The specimen exhibits a characteristic whitish, pruinose (powdery-coated) thallus. The black, elongated lirellae are partially embedded within the crustose body of the lichen. The scale bar on the far left indicates 1 mm per major division. (b) Apothecial cross-section: A transverse section of the lirella revealing the internal anatomy. The image displays several muriform spores (multi-celled with both horizontal and vertical septa) clustered within the hymenium. Using an ocular micrometer, these spores measure approximately 30–45 µm in length.

**15. *Graphis nuda* (H. Magn.) Staiger**

**Growth Form:** Crustose. **Taxonomic Notes:** Lirellae are prominent with entire labia and a carbonized exciple. Spores are muriform, hyaline, and react I+ blue-violet (Figure 5). **IUCN Red List Classification:** Data Deficient (DD): Insufficient data to assess risk. **Mangrove Host:** *Bruguiera cylindrica, Rhizophora stylosa*. **Reference:** Lücking et al. (2009)

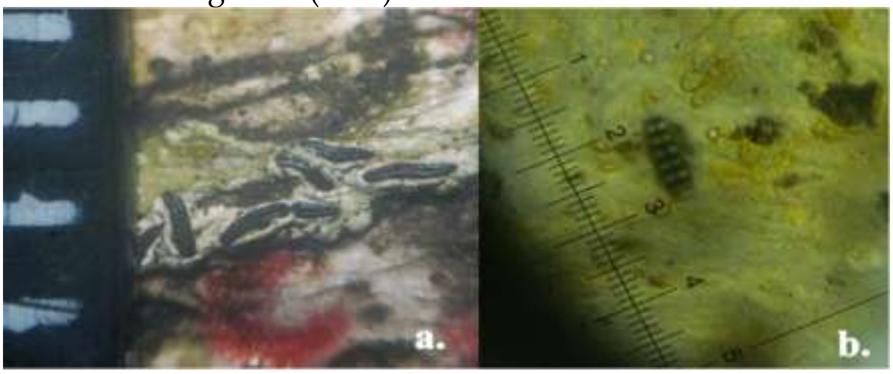

**Figure 4. Morphological and Microscopic Characteristics of *Graphis nuda*.**

(a). Macro view of the thallus and lirellae. The crustose, whitish-grey thallus is shown adhering to the bark substrate. The prominent, black, elongated fruiting bodies (lirellae) exhibit a characteristic "script-like" (graphidoid) appearance. A millimeter scale is provided on the left for size reference. (b). Microscopic view of a muriform spore. High-magnification view (with ocular micrometer) showing a single, heavily pigmented (melanized) muriform spore. The muriform spore displays distinct transverse and longitudinal septa, creating a grid-like "brick wall" internal structure. The spore measures approximately 25-30 µm in length.

**16. *Phaeographis* sp.**

**Growth Form:** Crustose. **Taxonomic Notes:** Apothecia are round to stellate, arranged in pseudostroma with exposed, blackish, pruinose discs. Spores are brown and transversely septate (I-); hymenium reacts I+ bluish-purple. Distinguished from *Graphis* by brown spores and from *Sarcographa* by the lack of true stromata. **Mangrove Host:** *Sonneratia alba*, *Lumnitzera racemosa*. **Reference:** Archer (2001)

**Family Lecanoraceae**

**17. *Lecanora helva* Stizenb.**

**Growth Form:** Crustose. **Taxonomic Notes**: Young specimen with warty greenish thallus (yellowish-green due to usnic acid). Apothecia are lecanorine (thalline margin present) with pale brown discs. Spores are simple. Large crystals are present in the hypothecium; the epithecium contains granules soluble in K (Figure 6). **IUCN Red List Classification:** Least Concern (LC): Widespread and abundant. **Mangrove Host:** *Rhizophora mucronata*. **References:** Santos et al. (2023); Nash (2002)


**Figure 5. Morphological and Anatomical Characteristics of *Lecanora helva*.**

**(**a) Macroscopic view of a young specimen of *Lecanora helva* exhibiting a warty, greenish-yellow thallus. Prominent lecanorine apothecia are visible, characterized by their pale brown discs and distinct thalline margins. The black-and-white scale on the left indicates 1 mm per major division. (b) Microscopic section of a transverse section of the apothecium. The red arrow identifies simple (single-celled) spores within the hymenium, which typically measure approximately 10–15 µm in length. The blue arrow indicates large crystals concentrated in the hypothecium. The ocular micrometer scale at the bottom provides a reference for these internal structures.

**Family Opegraphaceae**

**18. *Opegrapha* cf. *astraea***

**Growth Form:** Crustose. **Taxonomic Notes:** Lirellae are elongate and often branched, showing an exposed pruinose disc and lateral carbonization. The hymenium is wide (I+ red); spores are I-, fusiform, and 3-7 septate. **Mangrove Host:** *Aegiceras floridum, Bruguiera cylindrica, Ceriops tagal*. **Reference:** Ertz and Diederich (2007)

**19. *Opegrapha* cf. *dimidiata***

**Growth Form:** Crustose. **Taxonomic Notes:** Defined by a dimidiate exciple (lacking at the base). Spores are I-, transversely septate, and hyaline (becoming brown with age). **Mangrove Host:** *Aegiceras floridum, Bruguiera cylindrica, Ceriops tagal*. **Reference:** Ertz and Diederich (2007)

**Family Pertusariaceae**

**20.** ***Lepra* cf. *albopunctata***

**Growth Form:** Crustose. **Taxonomic Notes:** Thallus gray to white. Apothecia are verruciform, often appearing as white, sorediate-like punctures. Spores are large, single or paired. **Mangrove host:** *Sonneratia alba*. **Reference**: Wei et al. (2017)

**21.** ***Lepra corallina* (L.) Hafellner**

**Growth Form**: Crustose. **Taxonomic Notes:** Thallus whitish-grey, covered in numerous, crowded isidia (coralloid outgrowths); typically sterile. Chemistry includes thamnolic acid. **IUCN Red List Classification**: Least Concern (LC): Widespread and abundant. **Mangrove Host:** *Rhizophora stylosa*, *Rhizophora mucronata*. **Reference:** Wei et al. (2017)

**22.** ***Lepra corallina* var. *minor***

**Growth Form:** Crustose. **Taxonomic Notes**: Distinguished from the nominal variety by smaller isidia or finer thalline granulation**. IUCN Red List Classification:** Least Concern (LC): Widespread and abundant. **Mangrove Host:** *Rhizophora mucronata*. **Reference:** Wei et al. (2017)

**23.** ***Pertusaria* sp.**

**Growth Form:** Crustose. **Taxonomic Notes:** Specimen is very young. Genus characterized by crustose thallus, verruciform apothecia (wart-like), and large, thick-walled ascospores (1-8 per ascus). **Mangrove Host:** *Sonneratia alba*. **Reference:** Archer et al. (2009)

**Family Physciaceae**

**24.** ***Heterodermia* cf. *tremulans***

**Growth Form:** Foliose. **Taxonomic Notes:** Lobes not linear; heavily sorediate on lamina; soralia typically marginal to subapical (labriform). Shiny lower cortex (corticate) and rhizinate. **Mangrove Host**: *Rhizophora stylosa*. **Reference:** Mongkolsuk et al. (2015)

**25.** ***Heterodermia* sp.**

**Growth Form:** Foliose. **Taxonomic Notes:** Upper surface sorediate; medulla K+ red. Lower surface lacking cortex (ecorticate), rhizines blackening. Likely *H. comosa* or *H. obscurata* group. **Mangrove Host:** *Bruguiera cylindrica, Ceriops tagal*. **Reference:** Mongkolsuk et al. (2015)

**Family Pyrenulaceae**

**26.** ***Pyrenula* sp.**

**Growth Form:** Crustose. **Taxonomic Notes:** Thallus olive-green with perithecia (often covered by clypeus). Spores brown, degenerate, one appearing muriform. **Mangrove Host:** *Sonneratia alba*. **Reference**: Aptroot (2012)

**Family Ramalinaceae**

**27.** ***Bacidia*** **cf.** ***arceutina***

**Growth Form**: Crustose. **Taxonomic Notes**: Thallus showing biatorine apothecia. Section reveals K+ violet/blue hymenium and long, multisegmented (3-7+ septa) acicular ascospores. **Mangrove Host**: *Sonneratia alba*. **Reference**: Ekman (2001)

**28.** ***Biatora*** **sp.**

**Growth Form:** Crustose. **Taxonomic Notes:** Young specimen; thallus showing pustular soralia. Genus typically lacks a thalline margin (biatorine exciple); photobiont chlorococcoid. **Mangrove Host**: *Sonneratia alba*. **Reference:** Printzen and Tønsberg (1999)

**Family Stereocaulaceae**

**29.** ***Lepraria*** **sp. 1**

**Growth Form:** Crustose. **Taxonomic Notes:** Thallus entirely granular/leprose with very fine soredia; lacking cortex and apothecia. "Fine," Soredia suggests *L. incana* or *L. finkii*. **Mangrove Host:** *Rhizophora stylosa*, *Rhizophora mucronata, Excoecaria agallocha, Avicennia lanata*, *Avicennia lanata*. **Reference:** Lendemer (2011)

**30.** ***Lepraria*** **sp. 2**

**Growth Form:** Crustose. **Taxonomic Notes:** Thallus creamy, composed of granular soredia. Differentiated by coarser consoredia and cream coloration; possibly *L. lobificans* group. **Mangrove Host**: *Sonneratia alba*. **Reference:** Lendemer (2011)

**31.** ***Lepraria*** **sp. 3**

**Growth Form:** Crustose. **Taxonomic Notes:** Thallus whitish, leprose (fine soredia); sterile. **Mangrove Host:** *Avicennia lanata*. **Reference:** Lendemer (2011)

The enumerated mangrove lichen species are distributed across the selected sampling sites as illustrated in Figure 7.

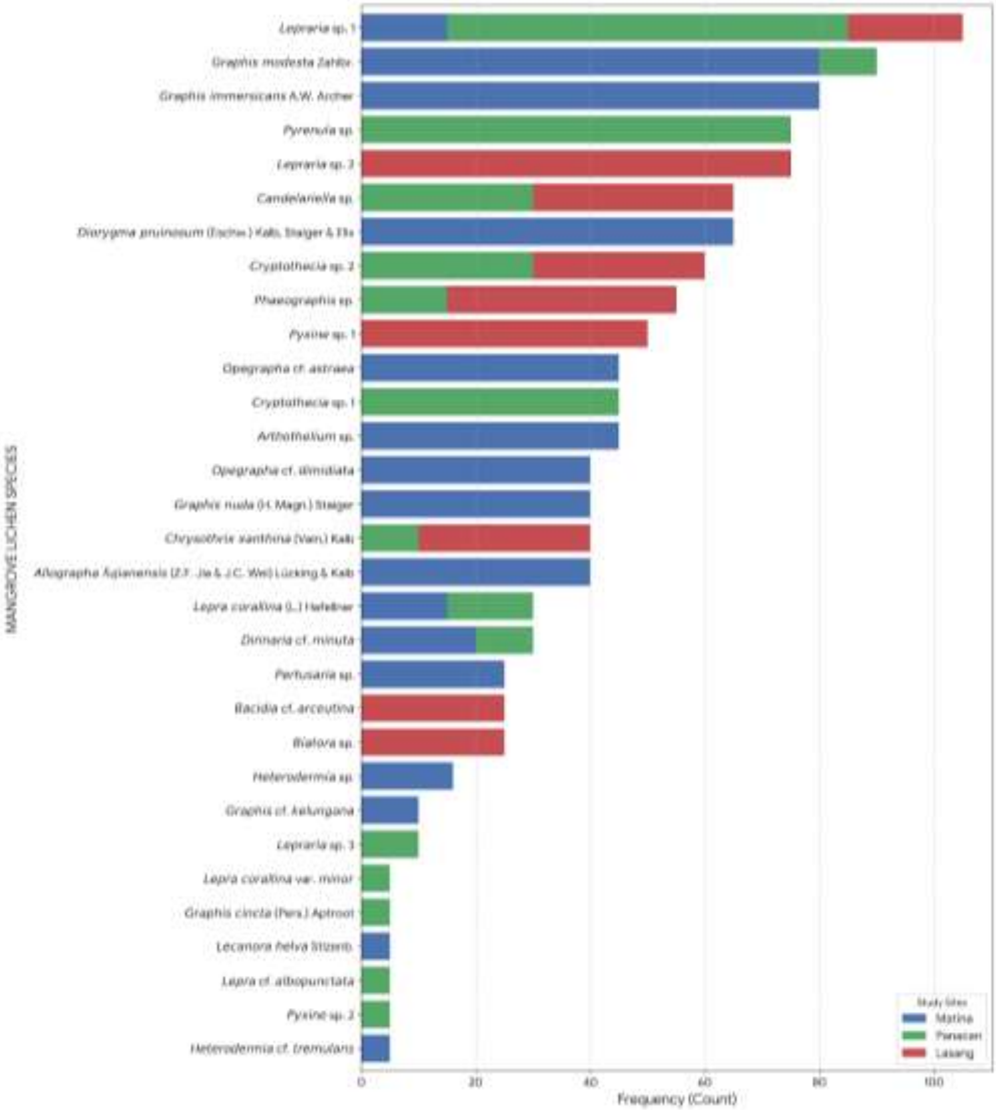


**Figure 6. Species Composition and Distribution of Mangrove Lichens in the Selected Sites in Davao City, Philippines**

***Diversity of mangrove lichens in Davao City***

Table 1 details the lichen diversity indices across the surveyed mangrove forests. Among the surveyed locations, Matina emerges as the principal reservoir of lichen diversity, exhibiting the highest species richness and Shannon–Wiener diversity. While Panacan recorded the highest Margalef's richness index, Matina's overall assemblage demonstrates a highly complex and equitable distribution.

Table 1. Lichen Diversity Indices in the Davao City Mangrove Forests

| | Matina | Panacan | Lasang |
|---|---|---|---|
| **Species Richness_S** | 16 | 15 | 9 |
| **Individuals** | 546 | 340 | 330 |
| **Dominance_D** | 0.09144 | 0.1298 | 0.1296 |
| **Simpson_1-D** | 0.9086 | 0.8702 | 0.8704 |

| | | | |
|---|---|---|---|
| **Shannon_H** | 2.538 | 2.314 | 2.125 |
| **Evenness_e^H/S** | 0.7911 | 0.6743 | 0.9306 |
| **Margalef** ($D_{mg}$) | 2.38 | 2.402 | 1.38 |

**Note:** Values are based on ecological diversity indices where *S* is the number of taxa and *N* is the total number of individuals. Shannon_H represents the Shannon-Wiener diversity index; Evenness_e^H/S represents Buzas and Gibson's evenness; Dominance_D ranges from 0 (all taxa equally present) to 1 (one taxon dominates completely).

In contrast, the Lasang site supports a comparatively depauperate lichen community, recording the lowest species richness and Shannon diversity. This site is marked by biotic homogenization and the highest recorded dominance. Although Lasang exhibits the highest evenness, this apparent uniformity among fewer species points to a simplified community structure in which generalists prevail due to the loss of specialized niches.

## DISCUSSION

The recorded taxa reveal a well-established lichenized fungal community across the Matina, Panacan, and Lasang mangrove sites, characterized by a clear dominance of crustose growth forms. This dominance is consistent with global mangrove patterns, where crustose lichens possess structural adaptations that enable firm attachment to substrates subjected to periodic tidal inundation (Logesh et al., 2012; Panda et al., 2017). Taxonomic richness is largely driven by the family Graphidaceae, reflecting pantropical trends in smooth-barked hosts where subtle micro-anatomical characters are essential for delimiting cryptic species (Lücking et al., 2009). In contrast, Pyrenulaceae—typically co-dominant in inventories of mature mangrove stands—was markedly underrepresented, being confined to a single *Pyrenula* specimen with degenerate spores (Weerakoon et al., 2012). This limited representation, together with the prominence of sterile and vegetatively reproducing taxa, may indicate ecological stress or reflect natural environmental filtering typical of mangrove substrates. Under disturbance theory, shifts in dominance structure are often interpreted as signals of environmental instability or ongoing recovery processes (Holling, 1973; Connell, 1978). Similarly, lichen assemblages dominated by asexual, vegetative strategists have been linked to frequently disturbed or unstable substrates. However, the strong environmental filtering intrinsic to mangrove ecosystems remains an equally plausible explanation.

The taxonomic composition recorded broadly accords with mangrove lichen inventories from other Philippine coastal regions, yet also reveals notable biogeographic nuances. Surveys from Calabarzon documented approximately 40 manglicolous species, with Graphidaceae likewise dominating crustose assemblages, underscoring the family's adaptation to tropical corticolous substrates (Aptroot & Lücking, 2016). However, the Davao City assemblages exhibit a comparatively higher proportion of sterile and vegetatively reproducing taxa, such as species of *Lepraria* and *Chrysothrix*, implying that urban mangrove fragments in Mindanao may experience stronger ecological filtering than less urbanized sites in Luzon (Ellis, 2012). Evidence from Pangasinan indicates that newly described Graphidaceae species are more frequently associated with relatively undisturbed mangrove stands. In contrast, the present results demonstrate that fragmented and regenerating mangrove systems in Davao City can still sustain considerable graphidoid diversity. This contrast highlights the resilience of crustose Graphidaceae under moderate anthropogenic pressure and supports their role as early colonizers during mangrove recovery (Lücking et al., 2009). More broadly, the predominance of crustose forms and the scarcity of Pyrenulaceae parallel observations from Indo-Pacific mangrove systems, where tidal inundation, bark salinity, and substrate instability selectively favor tightly adherent thalli with efficient water-regulation strategies (Aptroot & Lücking, 2016).

The ecological health and structural complexity of these sites are further reflected in their diversity indices and species specialization. The occurrence of sexually reproducing specialists such as *Diorygma pruinosum* and *Allographa fujianensis* in certain areas indicates sustained microclimatic stability and advanced forest maturity, conditions that favor the persistence of ecologically sensitive specialists (Rivas Plata et al., 2012). Low dominance values coupled with high Simpson diversity further suggest a stable community structure with minimal competitive exclusion. This complexity is characteristic of mature mangrove systems, whose structural heterogeneity mitigates the physiological stresses imposed on epiphytic lichens within coastal–urban environments (Logesh et al., 2012). When contextualized with previous Philippine mangrove inventories, the diversity indices observed in Davao City fall within the expected range for tropical mangrove lichen communities but reveal a gradient associated with urban disturbance intensity. Comparable studies from Southeast Asian mangroves reported Shannon diversity values of 1.8–2.6, indicating that the Matina assemblage represents a relatively well-structured community despite its urban setting (Ellis, 2012). This suggests that protected urban mangrove reserves can function as refugia for corticolous lichen diversity, particularly for graphidoid specialists sensitive to microclimatic stability. In contrast, the Lasang site contained an assemblage reflecting a shift toward stress-tolerant generalists and pollution-resistant bioindicator taxa, such as *Pyxine*, consistent with ecosystems shaped by anthropogenic pressures, reduced stand age, and compromised air quality (Rivas Plata et al., 2012; Aptroot & Herk, 2007).

Beyond ecological drivers, the high proportion of species classified as Data Deficient (DD) underscores the persistent "Linnean Shortfall" in Philippine mycology—the gap between known taxa and our understanding of their actual distributions (Haelewaters et al., 2024). In this context, records of species such as *Chrysothrix xanthina* are of particular conservation value, as they contribute critical occurrence data necessary for advancing these taxa from Data Deficient to formally assessed categories in future conservation planning. Furthermore, most taxa identified only to the genus level are categorized as Data Deficient due to the lack of species-level identification and regional population data (IUCN, 2020). Collectively, these findings extend the known distribution of several pantropical taxa and reinforce the view that the intricate relationship between host-bark microtopography and site-level disturbance gradients structures mangrove lichen communities.

## CONCLUSIONS AND RECOMMENDATIONS

In this context, the study indicated that the community structure was dominated by graphidoid and arthoniaceous crustose taxa characteristic of mangrove-adapted corticolous assemblages. Moreover, by producing the first taxonomic record of mangrove lichens in Davao City, the research fills a substantial regional data gap.

Moreover, the diversity indices indicate that ecological conditions across sites differ significantly. Matina is a "biodiversity reservoir" for Graphidaceae, whereas Lasang is under stress from human impacts, as evidenced by the dominance of opportunistic "dust lichens" such as *Lepraria* spp. By recording 31 taxa with the majority currently listed as Data Deficient or not yet evaluated by the IUCN Red List, the "Linnean Gap" is gradually being bridged. The designation of a species as Data Deficient indicates that insufficient data are available to assess its extinction risk, often leading to its exclusion from conservation financing and legal protection. Due to their lack of management priority until further research is done, this classification puts species in a "conservation purgatory" where they may experience silent extinction. Thus, the importance of preserving the remaining mangrove forests in Davao City, which are important refuges for the fungal diversity of the Philippines, is emphasized.

The results of this study were endorsed and presented to the Department of Environment and Natural Resources – Region XI, Philippines, for future conservation efforts. Further, the taxonomic knowledge generated in this study was used in the field of education, through biology-related disciplines, to increase future researchers' awareness of the need for further research.

## FURTHER STUDY

It is strongly advised that future studies use Thin Layer Chromatography (TLC) or high-performance liquid chromatography (HPLC) to confirm the secondary metabolite profiles of these taxa, as species identification in this study was primarily based on morphoanatomical traits and standard chemical spot tests. Future research should combine longitudinal monitoring of air quality and water salinity across the Matina Aplaya, Panacan, and Lasang sites to better elucidate the physiological limits of these bioindicators in urbanized mangrove ecosystems.

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**REFERENCES**

Aptroot, A. (2002). New and interesting lichens and lichenicolous fungi in Brazil. *Fungal Diversity*, 9, 15–45. https://www.fungaldiversity.org/fdp/sfdp/9-2.pdf

Aptroot, A. (2012). A world key to the species of *Anthracothecium* and *Pyrenula*. *The Lichenologist*, 44(1), 5–53. https://doi.org/10.1017/S0024282911000624

Aptroot, A., & Herk, C. M. V. (2007). Further evidence of the effects of global warming on lichens, particularly those with *Trentepohlia* phycobionts. *Environmental Pollution*, 146(3), 716–720. https://doi.org/10.1016/j.envpol.2006.03.018

Aptroot, A., & Lücking, R. (2016). A revisionary synopsis of the Trypetheliaceae (Ascomycota: Trypetheliales). *The Lichenologist*, 48(6), 763–982. https://doi.org/10.1017/S0024282916000487

Archer, A. W. (2001). The lichen genera *Phaeographis* and *Phaeographina* (Graphidaceae) in Australia 2: Phaeographina—new reports and new species. *Telopea*, 9(2), 329–344. https://doi.org/10.7751/telopea20013006

Archer, A. W., Elix, J. A., Fischer, E., Killmann, D., & Sérusiaux, E. (2009). The lichen genus *Pertusaria* (Ascomycota) in Central Africa (Congo/Kivu, Rwanda, and Burundi) and Western Kenya. *Nova Hedwigia*, 88(3-4), 309–322. https://doi.org/10.1127/0029-5035/2009/0088-0309

Awasthi, D. D. (1975). *A monograph of the lichen genus Dirinaria*. Bibliotheca Lichenologica.

Awasthi, D. D. (1991). *Key to the microlichens of India, Nepal and Sri Lanka*. J. Cramer.

Berba, C. M. P., & Matias, A. M. A. (2022). State of biodiversity documentation in the Philippines: Metadata gaps, taxonomic biases, and spatial biases in the DNA barcode data of animal and plant taxa in the context of species occurrence data. *PeerJ*, 10, e13146. https://doi.org/10.7717/peerj.13146

Brown, J. H., & Lomolino, M. V. (1998). Biogeography (2nd ed.). *Sinauer Associates*. https://doi.org/10.1002/mmnz.20000760118

Connell, J. H. (1978). Diversity in tropical rainforests and coral reefs. *Science*, 199(4335), 1302–1310. https://doi.org/10.1126/science.199.4335.1302

Costello, M. J., Vanhoorne, B., & Appeltans, W. (2015). Conservation of biodiversity through taxonomy, data publication, and collaborative infrastructures. *Conservation Biology*, 29(4), 1094–1099. https://doi.org/10.1111/cobi.12496

Das, K., Nikita, B. P., Rani, A., & Uniyal, P. L. (2021). Lichens as bioindicators and biomonitoring agents. *Environmental International Journal of Science and Technology, 15*, 18–25. https://tinyurl.com/ye248jkk

Ekman, S. (2001). Molecular phylogeny of the Bacidiaceae (Lecanorales, lichenized Ascomycota). *Mycological Research*, 105(7), 783–797. https://doi.org/10.1017/S0953756201004269

Ellis, C. J. (2012). Lichen epiphyte diversity: A species, community and trait-based review. *Perspectives in Plant Ecology, Evolution and Systematics*, 14(2), 131–152. https://doi.org/10.1016/j.ppees.2011.10.001

Ertz, D., & Diederich, P. (2007). Revision of the *Opegrapha* species with muriform ascospores (previously *Dictyographa*) (lichenized Roccellaceae). *The Lichenologist*, 39(2), 143–151. https://doi.org/10.1017/S0024282907006470

Fajardo, W. T., & Bawingan, P. A. (2019). Taxonomy and new records of Graphidaceae lichens in Western Pangasinan, Northern Philippines. *Philippine Journal of Systematic Biology*, 13(1), 40–54. https://doi.org/10.26757/pjsb2019b13006

Haelewaters, D., Matthews, T. J., Wayman, J. P., Belvaux, B., Piquet, A., & Pfister, D. H. (2024). Biological knowledge shortfalls impede conservation efforts in poorly studied taxa—A case study of Laboulbeniomycetes. *Journal of Biogeography*, 51(1), 29–39. https://doi.org/10.1111/jbi.14725

Hammer, Ø., Harper, D. A. T., & Ryan, P. D. (2001). PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica,* 4(1), 9. https://palaeo-electronica.org/2001_1/past/issue1_01.htm

Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics*, 4, 1–23. https://doi.org/10.1146/annurev.es.04.110173.000245

Hortal, J., de Bello, F., Diniz-Filho, J. A. F., Lewinsohn, T. M., Lobo, J. M., & Ladle, R. J. (2015). Seven shortfalls that beset large-scale knowledge of biodiversity. *Annual Review of Ecology, Evolution, and Systematics*, 46, 523–549. https://doi.org/10.1146/annurev-ecolsys-112414-054400

International Union for Conservation of Nature. (2020). IUCN Environmental Impact Classification for Alien Taxa (EICAT) Guidelines (Version 1.1). https://iucn.org/sites/default/files/2023-02/eicat-guidelines-final-v1.1.pdf

International Union for Conservation of Nature. (2024). The IUCN Red List of Threatened Species (Version 2023–1). http://www.iucnredlist.org

Ismail, A., Hakim, N. S. A., Radzun, K. A., & Syazwan, S. A. (2024). Abiotic factors and distribution patterns of epiphytic lichens inhabiting different altitudes. *Biodiversitas*, 25(9), 3084–3094. https://doi.org/10.13057/biodiv/d250930

IUCN SSC Lichen Specialist Group. (2024). Report of the Lichen Specialist Group on unlisted species and habitat uniqueness. *International Union for Conservation of Nature*. http://www.iucn.org

Jia, Z. F., & Wei, J. C. (2008). *Graphis fujianensis*, a new species of Graphidaceae from China. *Mycotaxon*, 104, 107–110. https://doi.org/10.5962/p.414382

Joshi, S., Upreti, D. K., Divakar, P. K., Lumbsch, H. T., & Lücking, R. (2018). A re-evaluation of thelotremoid Graphidaceae (lichenized Ascomycota: Ostropales) in India. *The Lichenologist*, 50(6), 627–678. https://doi.org/10.1017/S0024282918000439

Kalb, K. (2001). New or otherwise interesting lichens I. *Bibliotheca Lichenologica*, 78, 141–168. https://tinyurl.com/8xmf2rke

Kalb, K., Staiger, B., & Elix, J. A. (2004). A monograph of the lichen genus *Diorygma*—a first attempt. *Symbolae Botanicae Upsalienses*, 34(1), 133–181. https://tinyurl.com/yc2waf9w

Kantvilas, G. (2021). A synopsis of the genus *Arthothelium* (Arthoniales) in Tasmania. *The Lichenologist*, 53(6), 415–431. https://doi.org/10.1017/S0024282921000402

Ladle, R., & Hortal, J. (2013). Mapping species distributions: Living with uncertainty. *Frontiers of Biogeography*, *5*(1). https://doi.org/10.21425/F55112942

Lee, B. G., & Hur, J. S. (2022). A new species and four new records of *Bacidia* (Lecanorales, Ramalinaceae) from South Korea, with a key to Korean species. *MycoKeys*, 93, 107–125. https://doi.org/10.3897/mycokeys.93.89283

Lendemer, J. C. (2011). A standardized morphological terminology and descriptive scheme for *Lepraria* (Stereocaulaceae). *The Lichenologist*, 43(5), 379–399. https://doi.org/10.1017/S0024282911000326

Logesh, A. R., Upreti, D. K., Kalaiselvam, M., & Nayaka, S. (2012). Lichen flora of Pichavaram and Muthupet mangroves (Southeast coast of India). *Mycosphere*, 3(6), 884–888. https://doi.org/10.5943/mycosphere/3/6/1

Lucban, M. C., & Paguirigan, J. A. G. (2019). Occurrence of manglicolous lichens in Calabarzon, Philippines. *Studies in Fungi*, 4(1), 263–273. https://doi.org/10.5943/sif/4/1/28

Lücking, R., & Kalb, K. (2018). Formal instatement of *Allographa* (Graphidaceae): How to deal with a hyperdiverse genus complex with cryptic differentiation and paucity of molecular data. *Herzogi*a, 31(1), 535–561. https://doi.org/10.13158/heia.31.1.2018.535

Lücking, R., Archer, A. W., & Aptroot, A. (2009). A world-wide key to the genus *Graphis* (Ostropales: Graphidaceae). *The Lichenologist*, 41(4), 363–452. https://doi.org/10.1017/S0024282909008305

Magurran, A. E. (2004). *Measuring biological diversity*. Blackwell Science. https://tinyurl.com/56vfstyf

Mongkolsuk, P., Meesim, S., Poengsungnoen, V., Buaruang, K., Schumm, F., & Kalb, K. (2015). The lichen family Physciaceae in Thailand—II. Contributions to the genus *Heterodermia* sensu lato. *Phytotaxa*, 235(1), 1–66. https://doi.org/10.11646/phytotaxa.235.1.1

Mora, C., Tittensor, D. P., Adl, S., Simpson, A. G. B., & Worm, B. (2011). How many species are there on Earth and in the ocean? *PLOS Biology, 9*(8), e1001127. https://doi.org/10.1371/journal.pbio.1001127

Nash, T. H. (2002). *Lichen flora of the Greater Sonoran Desert Region: Most of the microlichens, balance of the macrolichens, and the lichenicolous fungi* (Vol. 2). Lichens Unlimited, Arizona State University. https://tinyurl.com/54na3dtt

Nayaka, S. (2014). *Methods and techniques in collection, preservation and identification of lichens.* In S. Jha (Ed.), Plant taxonomy and biosystematics:

Classical and modern methods (pp. 101–105). New India Publishing Agency. https://tinyurl.com/5axykx9w

Neyens, T., Diggle, P. J., Faes, C., Beenaerts, N., Somers, B., & Hens, N. (2019). Mapping species richness using opportunistic samples: A case study on ground-floor bryophyte species richness in the Belgian province of Limburg. *Scientific Reports*, 9, 19122. https://doi.org/10.1038/s41598-019-55593-x

Panda, M., Murthy, T. V. R., Samal, R. N., Lele, N., Patnaik, A. K., & Chand, P. K. (2017). A comparative study of manglicolous lichens and their distribution inside Bhitarkanika National Park (Odisha), India. *Studies in Fungi,* 2(1), 1–13. https://doi.org/10.5943/sif/2/1/1

Patiño, J., & Vanderpoorten, A. (2021). Island biogeography: An avenue for research in bryology. *Bryophyte Diversity and Evolution, 43*(1), 206–220. https://doi.org/10.11646/bde.43.1.15

Printzen, C., & Tønsberg, T. (1999). The lichen genus *Biatora* in northwestern North America. *The Bryologist*, 102(4), 692–713. https://doi.org/10.2307/3244251

Ram, T. J., & Sinha, G. P. (2016). A world key to *Cryptothecia* and *Myriostigma* (Arthoniaceae), with new species and new records from the Andaman and Nicobar Islands, India. *Phytotaxa*, 266(2), 103–114. https://doi.org/10.11646/phytotaxa.266.2.4

Reynolds, C. L., Er, O. A., Winder, L., & Blanchard, A. (2017). Distribution and community composition of lichens on mature mangroves (*Avicennia marina* subsp. *australasica*) in New Zealand. *PLoS ONE*, 12(7), e0180525. https://doi.org/10.1371/journal.pone.0180525

Rivas Plata, E., Lücking, R., & Lumbsch, H. T. (2012). A new classification for the family Graphidaceae (Ascomycota: Lecanoromycetes: Ostropales). *Fungal Diversity*, 52, 107–121. https://doi.org/10.1007/s13225-011-0135-8

Rogers, R. W. (1986). The genus *Pyxine* (Physciaceae, lichenized Ascomycetes) in Australia. *Australian Journal of Botany*, 34(2), 131–154. https://doi.org/10.1071/BT9860131

Santos, L. A. D., Aptroot, A., Lücking, R., & Cáceres, M. E. S. (2023). *Lecanora* s. lat. (Ascomycota, Lecanoraceae) in Brazil: DNA barcoding coupled with phenotype characters reveals numerous novel species. *Journal of Fungi*, 9(4), 415. https://doi.org/10.3390/jof9040415

Scheffers, B. R., Joppa, L. N., Pimm, S. L., & Laurance, W. F. (2012). What we know and don't know about Earth's missing biodiversity. *Trends in Ecology & Evolution, 27*(9), 501–510. https://doi.org/10.1016/j.tree.2012.05.008

Tatipamula, V. B., Killari, K. N., Polimati, H., Prasad, G. V., & Enamala, S. (2021). Chemical and biological investigations on mangrove associated lichens (manglicolous lichens) from India. *Indian Journal of Pharmaceutical Sciences*, 83(2), 186–194. https://doi.org/10.36468/pharmaceutical-sciences.764

Weerakoon, G., Aptroot, A., Lumbsch, H. T., Wolseley, P. A., Damayanthi, P. M., Karunaratne, S., & Wijeyaratne, S. C. (2012). New molecular data on Pyrenulaceae from Sri Lanka reveal two well-supported groups within this family. *The Lichenologist*, 44(5), 639–647. https://doi.org/10.1017/S0024282912000333

Wei, X., Schmitt, I., Hodkinson, B., Flakus, A., Kukwa, M., Libertuofer, S., & Lumbsch, H. T. (2017). Circumscription of the genus *Lepra*, a recently resurrected genus to accommodate the "Variolaria"-group of Pertusaria sensu lato. *PLoS ONE*, 12(7), e0180284. https://doi.org/10.1371/journal.pone.0180284

Westberg, M. (2005). *The lichen genus Candelariella in western North America*. Lund University. https://tinyurl.com/yvxxm9e3

Whittaker, R. J., Araújo, M. B., Jepson, P., Ladle, R. J., Watson, J. E. M., & Willis, K. J. (2005). *Conservation biogeography: Assessment and prospect. Diversity and Distributions*, 11(1), 3–23. https://doi.org/10.1111/j.1366-9516.2005.00143.x