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Species Diversity of Lichens in Curug Sadim, Sagalaherang District, Subang, West Java

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ABSTRACT

Despite its ecological significance, including its function as a sink for pollutants, a provider of oxygen, and a bioindicator of air quality, a comprehensive study of lichen diversity in Subang, West Java, has not been conducted. The objective of this study is to analyze the diversity of lichen found in the Curug Sadim natural tourism area, Subang. Data collection was carried out through the implementation of the cruising method at three observation stations. The results of this study indicated the presence of ten lichen species, classified into eight families, Namely *Caloplaca* sp. (Teloschistaceae), *Cladonia* sp. (Cladoniaceae), *Cryptothecia scripta* (Arthoniaceae), *Cryptothecia striata* (Arthoniaceae), *Dirinaria* sp. (Caliciaceae), *Flavoparmelia caperata* (Parmeliaceae), *Graphis scripta* (Graphidaceae), *Leptogium cyanescens* (Collemataceae), *Parmotrema hypotropum* (Parmeliaceae), and *Phlyctis* sp. (Phlyctidaceae). These lichen species are found attached to substrates such as trees and rocks, and they exhibit various thalus types, including fruticose, crustose, and foliose. The presence of lichen with high variation indicates that the environment of Curug Sadim is relatively clean and supports the survival of bioindicator organisms. These findings are of significant importance in light of their contribution to our understanding of local biodiversity and the potential of lichen as a bioecological indicator in monitoring environmental quality.

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1. INTRODUCTION

Lichen is an organism that arises from the symbiosis between fungi (mycobionts) and algae or cyanobacteria (photobionts/phycobionts). The relationship between algae and fungi is symbiotic, with algae providing energy through photosynthesis and fungi offering shelter (Yuwen, *et al*., 2024). Lichen populations have the capacity to thrive in a variety of habitat types that are widely distributed in nature. There are about 2500 species of lichen known to exist in Indonesia (Pratama & Trianto, 2020). Lichens are capable of thriving in a variety of environmental conditions, including dry and humid areas, as well as high and low altitudes. Lichens are found on a variety of substrates, including bark, tree bark, soil surfaces, rocks, and attached to leaves and walls. In addition, lichen has been identified as a pioneering species that thrives in harsh and arid environments, thereby creating conditions conducive to the proliferation of other organisms (Budel & Friedl, 2021).

Lichens act as environmental bioindicators. Bioindicators are groups of organisms whose presence is closely related to certain environmental factors that determine the health of an environment. Lichens are highly sensitive to pollution, and their presence indicates good air quality. The farther away they are from air pollution, the greater their diversity (Jahja *et al*., 2025).

Research on lichens, especially in West Java, is still limited. Some studies that have been conducted are lichen diversity in the Greater Bandung area as a bioindicator of air quality, which shows that lichen diversity decreases with increasing air pollution, especially in industrial or heavy traffic areas, while the Curug Cimahi area has the highest lichen diversity value (Saragih, 2024). In addition, another study on the diversity and phenetic relationships of the Usnea genus in the Cisanti Forest area, Bandung Regency, which successfully identified 23 *Usnea* species from three main subgenus, namely *Usnea*, *Eumitria*, and *Dolichousnea*, using morphological approaches and phenetic analysis to establish kinship relationships between species (Kusmoro, *et al.* 2025). Other research on the Usnea genus includes a study of its potential as a source of bioactive secondary metabolites and traditional medicine in Bogor, West Java (Jannah, *et al.* 2020; Jannah, *et al.,* 2022).

The few studies on lichens is evident in the limited scope of existing studies, which are predominantly confined to specific locations and taxa. Indeed, a considerable body of research concentrates exclusively on a single genus. To date, no research has been conducted on the diversity of lichens in the Curug Sadim area of Subang. Indeed, this area possesses significant ecological potential for study, particularly in the context of air quality monitoring, given its status as a naturally occurring destination that frequently attracts visitors. The objective of this study is to analyze the diversity of lichens in the Curug Sadim area, Subang, West Java. Given the role of lichens as bioindicators that are sensitive to environmental changes, this research is relevant to obtain a preliminary picture or database of lichens diversity in the region.

2. METHODS

This research was conducted in the Curug Sadim tourist area in Cicadas Village in the Sagalaherang District of the Subang Regency (**Figure 1**). Data was collected on March 22-23, 2025. Curug Sadim is located in the Nusantara VII tea plantation area and has a waterfall with a height of ± 10 meters and a river with clear water flowing from the waterfall. The Curug Sadim natural tourist area is on a fairly high plateau with an altitude of approximately 1,000 meters above sea level. The area is surrounded by plantations and trees, primarily bamboo and ferns, and has not too dense vegetation. The air in the research area is clean and cool. The soil is brownish with a slightly sandy texture. Because this location is a tourist spot, the soil texture has been adjusted with rocks to improve accessibility to the Curug Sadim area.

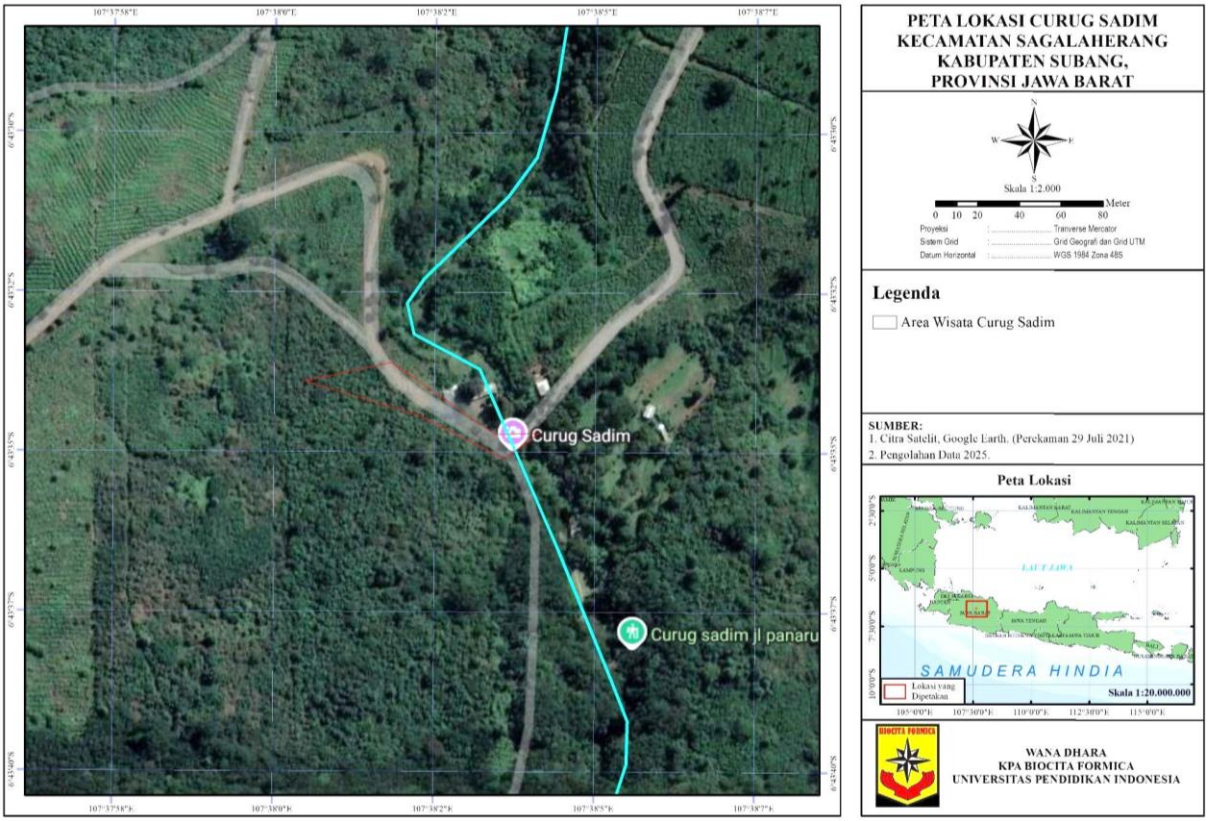

Figure 1. Location of area study

Lichen sampling was conducted using the cruising method, which involves direct observation and exploration of each location point that can represent the types of ecosystems or vegetation in the area under study (Rugayah *et al*., 2004; Hartini, 2011). The data were collected through the exploration of three distinct stations. Station 1 is located upstream of the river adjacent to the waterfall. Station 2 corresponds to the point of bifurcation between the two paths, specifically the camp area. Station 3 was located downstream from the area adjacent to the entrance.

The identification of lichen species was conducted at the species level, employing a range of references to support this determination. These references included the field manual Guide to Common Macrolichens and Bryophytes of the Umatilla National Forest (Kelly, 2006), the Field Oriented Keys to the Florida Lichens (Rosentreter *et al*., 2022), and the website of Global Biodiversity Information Facility (GBIF, 2025). Furthermore, the conservation status of each species was evaluated based on data from the International Union for Conservation of Nature's Red List of Threatened Species (IUCN, 2025). The percentage value of abundance of each species of lichen was calculated by comparing the number of individuals of a given species to the total number of lichen individuals found (Fisher, *et al*., 1943; Kempton, 1979). Additionally, lichens in Curug Sadim employed the Shannon-Wiener Diversity Index formula to calculate the diversity index (Michael, 1984; Magurran, 1988), utilizing the following formula:

$$\mathbf{H}' = -\sum pi \ln pi, \text{ where } pi = \frac{ni}{N}$$

The formula refer to; ***pi*** is the proportion of individuals found in the species, ***ni*** is the individuals number of a species, and ***N*** is the total individuals number of all species. The value scale of diversity index is H' < 1.5, indicating the low diversity, the value of H'1.5–3.5 indicates the moderate diversity, and the value of H' > 3.5 indicates that the diversity is high (Wilhm & Dorris, 1968).

3. RESULTS AND DISCUSSION

A total of 10 species of lichen were identified in Curug Sadim, classified into 8 distinct families (**Table 1**). Lichens family that consists of more than one genus and species is Parmeliaceae. Parmeliaceae is characterized by a prevalence of a particular species within its natural environment (Kusmoro, *et al.,* 2018; Moya, *et al.,* 2021).

Table 1. List of lichen species in Curug Sadim, Subang

No.	Family	Species	Habitat	IUCN Status
1	Arthoniaceae	*Cryptothecia striata*	Tree	-
2	Arthoniaceae	*Cryptothecia scripta*	Tree	-
3	Caliciaceae	*Dirinaria* sp.	Tree	-
4	Cladoniaceae	*Cladonia* sp.	Tree	-
5	Collemataceae	*Leptogium cyanescens*	Tree	-
6	Graphidaceae	*Graphis scripta*	Tree	-
7	Parmeliaceae	*Flavoparmelia caperata*	Rock	Least Concern
8	Parmeliaceae	*Parmotrema crinitum*	Tree	Least Concern
9	Phlyctidaceae	*Phlyctis* sp.	Tree	-
10	Teloschistaceae	*Caloplaca* sp.	Rock	-

The Lichens species found in Curug Sadim mostly grow epiphytically on tree bark. A total of two species were identified as growing in proximity to the rocky substrates. This phenomenon can be attributed to the fact that the riparian area of Curug Sadim is still covered with an abundance of trees. However, the lichens species found in this area are not considered endangered. A significant proportion of these species are not included in the IUCN Red List assessment. A total of two species have been categorized as low risk or Least Concern (LC), such as *Flavoparmelia caperata* and *Parmotrema crinitum* from Parmeliaceae family (**Figure 2**).

Figure 2. Species of lichens in Curug Sadim. (A) *Caloplaca* sp., (B) *Cladonia* sp., (C) *Crytothecia scripta,* (D) *Cryptothecia striata,* (E) *Dirinaria* sp., (F) *Flavoparmelia caperata*, (G) *Graphis scripta,* (H) *Leptogium cyanescens,* (I) *Parmotrema hypotropum,* (J) *Phlyctis* sp.

Diagnostic description of Lichens in Curug Sadim

Caloplaca sp. Fries, T.M. (1861)

The thallus of this species exhibits a yellowish-green hue when moist and transitions to a grayish-orange color when desiccated, with a crustose type. The thallus exhibits a diameter of approximately 10-15 centimeters, frequently encircled by a thin white or blackish prothallus that is distinctly observable at the periphery (Douglass, 2009). Another salient feature is the presence of dark orange disc-shaped apothecia that are uniformly distributed on the surface of the thallus, which is initially flat and then slightly protrudes as it grows (Gerault, 2013).

Cladonia sp. P.Browne (1756)

Cladonia exhibits a distinctive fruiting body morphology, manifesting as a cup- or horn-like structure, accompanied by a fruticose thallus type. This characteristic has led to the frequent appellation of this genus as "cup lichen" or "deer antler lichen." Cladonia is characterized by a thallus structure that is morphologically distinguished by a two-tiered configuration. The primary thallus, the first part of the organism, attaches directly to the substrate. It is diminutive and resembles scales or leaves. The second part is podetia, defined as an upright stem structure that grows from the primary thallus. The stem structure has a shape resembling a funnel or cup, which is the main characteristic of species in this genus (Hutasuhut, *et al.*, 2021). The natural habitat of Cladonia is typically in environments characterized by acidic soil, rock surfaces, or weathered wood.

Cryptothecia scripta G.Thor, Symb. Bot. Upsal. 32(1): 285 (1997)

Cryptothecia scripta is a crustose lichen. The thallus exhibits a notable degree of attachment to the substrate. The margins of the talus form a circle with a white outer border, while the talus itself is gray-green with a lighter center (Ramadhanti, 2021). On its adaxial surface, the thallus exhibits grayish-green or pale green powdery soredia, which are scattered over the surface (Ladd, 2002; Syafriadi, 2023).

Cryptothecia striata G.Thor, Bryologist 94: 278 (1991)

Cryptothecia striata is a crustose type of lichen. The species exhibits a thallus that is segmented into three distinct color zones, namely white in the peripheral and central regions and green between these two zones. The adaxial surface exhibits gray-green powdery soredia, which are scattered over the surface of the thallus. In contrast, the prothallus is white and characterized by a rounded growth pattern (Ladd, 2002; Syafriadi, 2023).

Dirinaria sp. (Tuck.) Clem., Gen. fung. (Minneapolis): 84 (1909).

Dirinaria thallus is characterized by greenish-gray lobes that are flat and tightly attached to the bark (Nasriyati, *et al*., 2018). The lobes of Dirinaria are folded and pruinose, exhibiting a gray-green coloration (Roziaty, *et al*., 2021). A comparison of the morphological characteristics of the Dirinaria group species reveals notable similarities, including the presence of flat lobes, a gray-green surface, a white medulla, and a reproductive method involving isidia or soredia (Melinda, 2020).

Flavoparmelia caperata (L) Hale, Mycotaxon, 25 (2): 604 (1986)

Flavoparmelia caperata is classified as a foliose lichen. This species has a sheet-shaped thallus with a greenish-white or bluish-green color. The species in question is characterized by its round lobes, the absence of soredia, the presence of isidia, and saucer-shaped apothecia (Nash, 2008; Syafriadi, 2023).

Graphis scripta (L) Ach., K. Vetensk-Acad. Nya Handl., 30: 145 (1809)

Graphis scripta is classified as a crustose lichen. This species has a grayish white thallus color. The adaxial surface of the thallus is characterized by the presence of apothecia that

manifest as lirellae. These structures are distinguished by their elongated, curved, branched morphology and black pigmentation (Hasanuddin, 2014). The species is tightly attached to its substrate making it difficult to separate without damaging the substrate (Syafriadi, 2023).

Leptogium cyanescens (Ach.) Korb., Syst. lich. germ., (Breslau): 420 (1855)

Leptogium cyanescens is characterized by a foliose thallus that exhibits a grayish to dark blue pigmentation. When subjected to moisture, the thallus surface attains a shiny appearance, while when dry, it acquires a pale bluish hue. The thallus exhibits a high degree of attachment to the substrate, with a diameter that can range from approximately 5-10 centimeters. The lobes are narrow, measuring approximately 2-5 millimeters in width and the edges are dotted with cylindrical isidia that function as tools for asexual reproduction (Kurniawan & Rochmah, 2021).

Parmotrema crinitum (Nyl.) Hale, Weber (1986)

Parmotrema crinitum has a broad, foliose thallus that is loosely attached to a tree trunk-like substrate. It is usually 8-15 mm wide and has gray-green, smooth, and sometimes shiny lobes that are up to 15 cm wide. This genus is characterized by ciliate margins (rhizine). Maculae (light spots) and soralia extend at the edges or slightly toward the center of the upper surface of the thallus, serving as organs of asexual reproduction (Armaleo, *et.a.,* 2008).

Phlyctis sp. (Wallr.) Flot., (1850)

Phlyctis is a group of lichens with crustose thallus. These lichens are epiphytic in nature and are found growing on the bark of trees in humid tropical rainforests. *Phlyctis* was identified as one of the dominant species of the Phlyctidaceae, with characteristics of a thin thallus that is strongly attached to the substrate and grayish or greenish in color (Sonia, *et al.*, 2024). Fruiting bodies, manifesting as apothecia, are typically diminutive and partially embedded within the thallus. The symbiotic algae found in the talus are typically green algae classified within the genus of Trebouxia (Purvis, *et al*., 1992).

A taxonomic classification of lichens is based on the morphology of the thallus, which can be crustose, foliose, or fruticose (Singh, *et al*., 2019). Crustose thalli are rough and flat, foliose thalli are sheet-like and piled together, and fruticose thalli are three-dimensional and grow upright or hang from trees and rocks (Amanda, *et.al*, 2024). The lichen found in the Curug Sadim area exhibits a high degree of diversity, with crustose, foliose, and fructicose forms being particularly prominent (**Figure 3**). The most prevalent type of lichen in the area is crustose thallus, which accounts for 50% of all observed species. Crustose lichen exhibits a greater degree of dominance in tropical ecosystems when compared with foliose and fruticose lichen (Miranda-González & McCune, 2020).

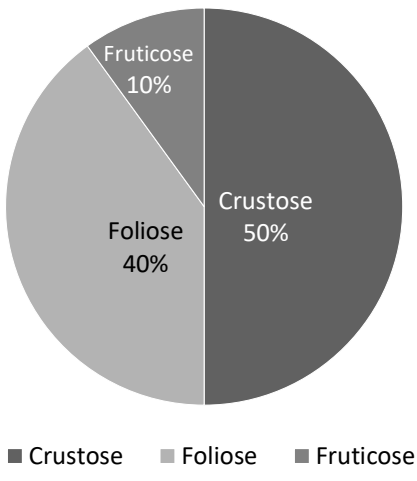

Figure 3. Lichens composition based on thallus type

The number of individuals of lichen species found in Curug Sadim varies. The species with the highest abundance percentage is Graphis scripta, at about 31.8% (**Figure 4)**. It has been documented that *Graphis* demonstrates a viable capacity for proliferation and dispersal at moderate altitudes within tropical environments, often found on trees or rocks (Kusmoro, *et al.,* 2019). Some lichen species were classified as having a low abundance of 4.5%, including *Parmotrema crinitum*, *Phlyctis* sp., *Leptogium cyanescens*, *Dirinaria* sp., and *Flavoparmelia caperata*. These species of lichens are found in minor numbers in Curug Sadim.

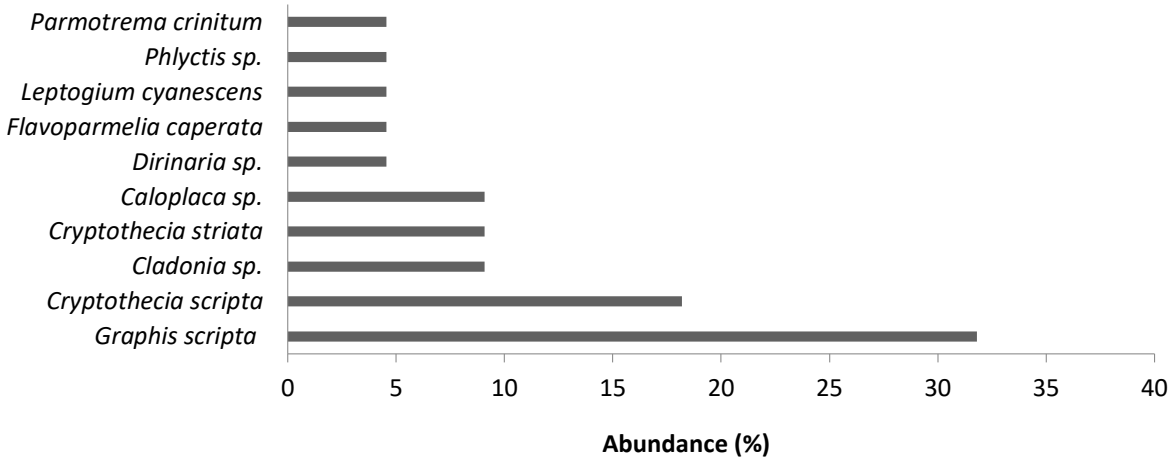

Figure 4. Abundance percentage of lichens in Curug Sadim

The species diversity index value of lichens in Curug Sadim was determined using the Shannon-Wiener index formula (H'). The Shannon-Wiener diversity index calculation yielded a result of **H'**=2.03. This finding indicates that the Curug Sadim area exhibits lichen species diversity that falls within the medium category. This condition is indicative of relatively good environmental quality and minimal pollution. The presence of diverse thalus types of lichen in this area serves as robust evidence for the notion that the ecosystem within this region is characterized by good health and balance (Lubek, *et al.,* 2021).

These lichens exhibit a high degree of adaptation to their environment, both in terms of the substrate on which they reside and the morphology of their thallus. For instance, *Flavoparmelia caperata*, a species found on rock surfaces, exhibits a high degree of tolerance to air pollution and is capable of survival in adverse environmental conditions. This finding indicates that lichen species can serve as effective environmental indicators, particularly in the context of monitoring air pollution levels. The ecological functions of lichens include the provision of oxygen, the absorption of pollutants, the promotion of succession, and the monitoring of air quality (Widodo, *et al.* 2023). Consequently, lichens can serve as bioindicator organisms for air pollution.

4. CONCLUSION

In conclusion, the diversity of lichens in the Curug Sadim area has 10 species of lichens belonging to 8 families. The most abundant population of lichen is *Graphis scripta.* Each species of lichen has different morphological characteristics and substrate preferences. The majority of lichen species are found to be associated with trees. Furthermore, most of the identified lichen species have a crustose thallus type. The diversity of lichens in Curug Sadim is classified as moderate diversity. The environmental conditions at the site continue to support the proliferation of the lichen community. This phenomenon serves as an indicator of the relatively favorable air quality in Curug Sadim. In addition, further efforts are necessary to monitor the habitat or ecosystem in the Curug Sadim area, with the objective of maintaining biodiversity in a sustainable state.

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6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

7. REFERENCES

Amanda, D., Purba, J. A., Simajuntak, D., and Rahmawati, S. (2024). Identifikasi lumut kerak (lichen) di sekitaran FMIPA Univeristas Negeri Medan. *Jurnal Ilmiah Multidisiplin Terpadu*, 8(6), 541–543.

Armaleo, D., Zhang, Y., and Cheung, S. (2008). Light might regulate divergently depside and depsidone accumulation in the lichen *Parmotrema hypotropum* by affecting thallus temperature and water potential. *Mycologia*, 100(4), 565–576.

Budel, B. and Friedl, T. (2021). *Life at Rock Surfaces: Challenged by Extreme Light, Temperature and Hydration Fluctuations*. Berlin (Germany): Walter de Gruyter GmbH & Co KG. 141–160 hlm.

Douglass, J. (2009). Irish Lichens. https://irishlichens.ie/pages-lichen/l-258.html. [Accessed 13 Juli 2025].

Fisher, R.A., Corbet, S., and Williams, C.B. (1943). The relation between the number of species and the number of individuals in a random sample of an animal population. *Journal of Animal Ecology,* 12(1), 42-58.

[GBIF] Global Biodiversity Information Facility. (2025). Free and Open Access to Biodiversity Data. https://www.gbif.org/. [Accessed 5 Juli 2025].

Gerault, A. (2013). Lichens Maritimes: *Caloplaca flavovirescens*. https://www.lichensmaritimes.org/index.php. [Accessed 14 Juli 2025].

Hartini, S. 2011, Tumbuhan paku di beberapa kawasan hutan di Taman Nasional Kepulauan Togean dan Upaya Konservasinya di Kebun Raya Bogor. *Berkala Penelitian Hayati*, 7A, 35–40.

Hasanuddin. (2014). *Botani Tumbuhan Rendah*. Banda Aceh: Unsyiah Press.

Hutasuhut, M. A., Febriani, H., and Devi, S. (2021). Identifikasi dan karakteristik habitat jenis lumut kerak di Taman Wisata Alam Sicikeh-Cikeh Kabupaten Dairi Sumatera Utara. *Jurnal Biolokus*. 4(1): 43.

[IUCN] International Union for Conservation of Nature. (2025). The IUCN Red List of Threatened Species. https://www.iucnredlist.org. [Accessed 30 Juni 2025].

Jahja, S. D., Lihawa, N. F., and Baderan, N. D. W. K. (2024). Peran Lichen sebagai bioindikator pencemaran logam berat timbal (Pb) di udara. *Hidroponik: Jurnal Ilmu Pertanian Dan Teknologi Dalam Ilmu Tanaman*, 2(1), 01–10.

Jannah, M., A`yun, Q., Rahmawati, A., Prasetya, E., and Hariri, M.R. (2022). Usnea in West Java: a potential source of bioactive secondary metabolites. *Berkala Penelitian Hayati,* 28(1), 26-31.

Jannah, M., Afifah, N., Hariri, M.R., Rahmawati, A., and Wulansari, T.Y.I. (2020). Study of lichen (*Usnea* spp.) as a traditional medicine in Bogor, West Java. *Berkala Penelitian Hayati,* 26(1), 32-38.

Kelly, A. M. (2006). *Guide to common macrolichens and bryophytes of the Umatilla National Forest*. Oregon (USA): Department of Agriculture, Forest Service, Umatilla National Forest.

Kempton, R.A. (1979). The Structure of Species Abundance and Measurement of Diversity. *Biometrics*, 35(1), 307-321.

Kurniawan, E. D. and Rochmah, S. (2021). Keanekaragaman Lichen di Kawasan Wisata Alam Kandung Kabupaten Tulungagung. *Jurnal Ilmu Biologi dan Pembelajarannya (BioEdu)*, 10(2), 95–102.

Kusmoro, J., Mayawatie, B., Budiono, R., Noer, I.S., Permatasari, R.E., Nurwahidah, A., Satriawati, R., Arum, D., Saragih, D.E., Widya, R., Jatnika, M.F., Afifmakarim, and Partasasmita, R. (2019). Short communication: Species diversity of corticolous lichens in the arboretum of Padjadjaran University, Jatinangor, Indonesia. *Biodiversitas,* 20(6), 1606-1616.

Kusmoro, J., Noer, I.S., Jatnika, M.F., Permatasari, R.E., and Partasasmita, R. (2018). Lichen diversity in geothermal area of Kamojang, Bandung, West Java, Indonesia and its potential for medicines and dyes. *Biodiversitas*, 19(6), 2335-2343.

Kusmoro, J., Raihan, R., Hermawan, W., and Hasan, R. (2025). Diversity and phenetic relationship of lichen genus Usneain Cisanti Forest area, Bandung District, West Java, Indonesia. *Biodiversitas,* 26(2), 583-600.

Ladd, D. (2002). *Lichen of Lower Ozark Region of Missouri and Arkansas*. Columbia: Nature Conservancy, Missouri Botanical Garden.

Lubek, A., Kukwa, M., Jaroszewicz, B., and Czortek, P. (2021). Shifts in lichen species and functional diversity in a primeval forest ecosystem as a response to environmental changes. *Forests*, 12(6), 686.

Magurran, A.E. (1988). *Ecological Diversity and Its Measurement*. New Jersey: Princeton University Press. 35–37 hlm.

Melinda, R., Zulfahmi, and Adriyanti, D. (2020). Keanekaragaman lumut kerak (lichen) di kawasan Hutan Larangan Adat Ghimbo Potai. *Jurnal Biologi Biolokus*, 3(2), 121–129.

Michael, P. (1984). *Ecological Methods forField and Laboratory Investigations*. New Delhi: Tata McGraw-Hill Publishing Company Limited.

Miranda-González, R. and McCune, B. (2020). The weight of the crust: Biomass of crustose lichens in tropical dry forest represents more than half of foliar biomass. *Biotropica*, 52(6), 1298-1308.

Moya, P., Molins, A., Škaloud, P., Divakar, P.K., Chiva, S., Dumitru, C., Molina, M.C., Crespo, A., and Barreno, E. (2021). Biodiversity patterns and ecological preferences of the photobionts associated with the lichen-forming genus Parmelia. *Frontiers in Microbiology,* 12, 1-14.

Nash, T.H. (2008). *Lichen Biology*. Cambridge: Cambridge University Press.

Nasriyati, T., Sugiyarto, and Sulistyaningsih, E. (2018). Analisis vegetasi lichen epifit di kawasan Tembalang, Semarang sebagai bioindikator pencemaran udara. *Jurnal Biologi*, 7(2), 55–60.

Pratama, A. and Trianto, M. (2020). Keanekaragaman Lichen di Hutan Mangrove Desa Tomoli Kabupaten Parigi Moutong. *BIO-EDU: Jurnal Pendidikan Biologi,* 5(3), 140-150.

Purvis, O.W., Coppins, B.J., Hawksworth, D.L., James, P.W., and Moore, D.M. (1992). *The Lichen Flora of Great Britain and Ireland*. London: Natural History Museum Publications and British Lichen Society.

Ramadhanti, Z.N., Harnum, I.A., Pratiwi, N.R., Putri, Z.W., Miarsyah, M., and Utami, A.W.A. (2021). Inventarisasi liken di kawasan Kebun Raya Bogor. *Proceeding of Biology Education*, 4(1), 120-129.

Rosentreter, R., DeBolt, A.M., and Kaminsky, B. (2022). *Field Oriented Keys to the Florida Lichens*. Boise, Idaho (USA): Boise State University.

Roziaty, E., Santhyami, Kusumadhani, A.I., and Asy'ari, M.I.B. (2021). Keanekaragaman lichen sebagai bioindikator kualitas udara di kawasan Kota Surakarta, Jawa Tengah. *Bioeksperimen*, 7(2), 66-73.

Rugayah, Retnowati, A., Windadri, F.I., and Hidayat, A. (2004). *Pengumpulan DataTaksonomi*: *Pedoman Pengumpulan Data Keanekaragaman Flora*. Bogor: Pusat Penelitian Biologi, Lembaga Ilmu Pengetahuan Indonesia.

Saragih, D. E., Irwanto, R. R., and Taufikurahman, T. (2024). Biomonitoring of air quality using lichen as bioindicator in the Greater Bandung area, West Java. *3BIO Journal of Biological Science Technology and Management*, 6(2), 256–266.

Singh, S., Arya, M., and Vishwakarma, S.K. (2019). Advancements in methods used for identification of lichens. *International Journal of Current Microbiology and Applied Sciences*, 8(8), 1450-1460.

Sonia, A., Lingga, R., and Fastanti, F.S. (2024). Keanekaragaman jenis lichen di Tahura Gunung Menumbing Kabupaten Bangka Barat Provinsi Kepulauan Bangka Belitung. *Berita Biologi*, 23(2), 215 –225.

Syafriadi, Z. (2023). *E-booklet Keanekaragaman Hayati Lichenes di Kampus Bina Widya Universitas Riau*. Pekanbaru: Universitas Riau.

Widodo, G.A., Kartikasari, D., Ichyaiddina, A.N., and Pitaloka, D. (2023). Keragaman lichen di kawasan wisata alam Kandung Kabupaten Tulungagung. *Radikula: Jurnal Ilmu Pertanian, 2*(1), 47–59.

Wilhm, J.L. and Dorris, T.C. (1968). Biological parameters for water quality criteria. *Bioscience*, 18(6), 477–481.

Yuwen, Z.H.U., Liyan, Y.U., and Tao, Z. (2024). Diversity and interactions of lichen mycobionts and photobionts in the Fildes Region, King George Island, maritime Antarctica. *Advances in Polar Science*, 35(3), 385-399.