LenteraBio
Berkala Ilmiah Biologi

LenteraBio, 2025; Volume 14, Issue 2: 251-265

p-ISSN: 2252-3979 e-ISSN: 2685-7871
https://journal.unesa.ac.id/index.php/lenterabio/index

Floristic Study of Moss Species in Halimun Camping Ground, Selabintana Resort, Mount Gede Pangrango National Park

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Article History:
Received:
12-December-2024
Revised:
26-May-2025
Available online:
31-May-2025
Published regularly:
31-May-2025

Abstract
Mount Gede Pangrango National Park (MGPNP) has a biodiversity of flora, fauna, and ecosystems that are important for preserving hydrological and climatic functions. Moss (Bryophyta), as a non-vascular flora, plays a role in maintaining water balance, nutrient cycle, and is an environmental bioindicator. This study aims to identify the diversity of moss in the Halimun Camping Ground, MGPNP, with a qualitative descriptive method. Samples were taken by purposive sampling at the Cibeureum waterfall path, identified morphologically in the laboratory, and classified using a species Identification Sheet and a microscope. The results of this study identified 23 moss species, including 18 species of true mosses (Bryopsida and Polytrichopsida), 4 species of liver mosses (Marchantiopsida and Jungermanniopsida), and 1 species of horn moss (Notothyladaceae). True mosses dominated, reflecting their adaptability to the area's microclimate, underscoring their role as ecological stabilizers

Keywords: Biodiversity; Bryophyta; Identification; MGPNP
How to Cite: Asharo RK, Pasaribu PO, Achmad FF, Karina, Mulyadi RS, Hidayatie F, Asih SD, Putri HE, 2025. Floristic Study of Moss Types in Halimun Camping Ground, Selabintana Resort, Mount Gede Pangrango National Park. LenteraBio; 14(2): 251-265.
DOI: https://doi.org/10.26740/lenterabio.v14n2.p251-265

INTRODUCTION

Indonesia's tropical climate supports rich biodiversity, including various types of moss (Lestiani *et al*., 2021). Moss (Bryophyta) is a group of simple plants commonly found on land, typically small in size, and growing on different substrates such as rocks, trees, wood, and soil. Moss is highly adaptable to both wet and dry environments, making it well-suited to Indonesia's geographical conditions (Endang *et al*., 2020). The diversity of moss in Indonesia reaches approximately 1,500 species, categorized into three classes: Hepaticae (liverworts), Musci (leaf mosses), and Anthocerotae (hornworts) (Pratama *et al*., 2022).

Moss growth is influenced by various environmental factors such as temperature, humidity, and light, with each species exhibiting different tolerance levels that affect their adaptability, species composition, and distribution. In tropical rainforests, where humidity is high and temperature variations occur, moss thrives in diverse microhabitats, from tree trunks and rocks to forest floors (Husain *et al*., 2022).

Ecologically, moss plays a crucial role in maintaining ecosystem balance by regulating water retention, preventing soil erosion, and supporting nutrient cycles, which contribute to soil fertility. Its dense structure helps trap moisture, creating a suitable environment for microorganisms and small invertebrates that are essential to the food web. Additionally, moss serves as a habitat and breeding ground for various organisms, including insects and amphibians, further enhancing biodiversity. As a pioneer plant, moss facilitates the colonization of barren surfaces, accelerating ecosystem recovery in disturbed areas by providing organic material that supports the establishment of other plant species. Moreover, its high sensitivity to pollutants and climate variations makes moss an effective bioindicator, widely used in environmental monitoring to assess air quality and ecosystem health (Bawaihaty *et al*., 2014).

Mosses, including liverworts, are vital components of tropical forest ecosystems, contributing to nutrient cycling, water retention, and creating microhabitats for various organisms (Gupta *et al*., 2015). In Indonesia's rich tropical landscapes, many protected areas remain underexplored in terms of

their moss flora. One important prior study is by Haerida (2009), titled "*Diversity of Lejeuneaceae from Surrounding Area of Bodogol Education Center and Conservation, Gunung Gede-Pangrango National Park*." This study documented 13 moss species from the Lejeunaceae family using an explorative method. Observation and collection are carried out from tree trunks, branches, and branches and then microscopic identification is carried out.

However, as environmental conditions in tropical forests shift due to climate variability and human activity, updated floristic surveys are needed to ensure the current composition of moss species is accurately documented. This is especially relevant for specific locations like Halimun Camping at the Selabintana Resort, where recreational use and microhabitat variation may influence moss communities differently than previously studied trail areas.

Comparable research in other Indonesian national parks, such as Mount Halimun Salak and Kerinci Seblat, has also revealed diverse moss assemblages shaped by altitude, forest structure, and microclimatic conditions (Ariyanti & Sulistijorini, 2011; Siregar *et al*., 2023). Studies across tropical Southeast Asia reinforce the sensitivity of moss diversity to environmental gradients, particularly moisture and light availability (Tan & Pócs, 2000). These insights underscore the importance of localized floristic studies to support biodiversity monitoring and conservation planning.

Therefore, the objective of this study is to conduct a floristic inventory of moss species in the Halimun Camping area, Selabintana Resort, Mount Gede Pangrango National Park. The aim is to document the composition and richness of moss species in this specific location, providing updated baseline data that can support future ecological assessments and conservation efforts in the region.

MATERIALS AND METHODS

The research was conducted on April, 2024 at the Halimun Camping Ground, Selabintana Resort, Mount Gede Pangrango National Park (MGPNP) (Figure 1) and the Plant Structure and Development Laboratory of the State University of Jakarta.

Mount Gede Pangrango National Park (MGPNP) in West Java, established in 1980, is one of Indonesia's oldest national parks, covering 24,270.80 hectares and encompassing Mount Gede, Mount Pangrango, and surrounding forests (Supriyady *et al*., 2020). MGPNP is rich in biodiversity, with diverse flora, fauna, and ecosystems. Selabintana Resort, a key area within MGPNP, spans 2,547.93 hectares at the foot of Mount Gede Pangrango in Sukabumi (Dendang, 2009). With temperatures ranging from 18°C to 25°C, humidity is about 80-90%, and average rainfall of about 3.000-4.000 mm per year (Wasis *et al*., 2023), it supports various plant species, from tall trees to undergrowth, making it crucial for conservation (Rahmawati, 2022). Beyond its ecological value, MGPNP plays a vital role in maintaining hydrological and climate balance, benefiting surrounding regions such as Bogor, Cianjur, Sukabumi, and Jakarta (Suroso, 2018).

The materials used in the research were moss and distilled water. The tools used to support the sustainability of this research include zip lock plastic, labels, cutters, tweezers, petri dishes, object glasses, cover glasses, light microscopes, and stereo microscopes.

The research used a qualitative descriptive method, namely the exploration method, based on Munir *et al*. (2024). The exploration method is a method carried out by exploring the area that is the habitat of moss at the Halimun Camping Ground, Selabintana Resort, Mount Gede Pangrango National Park (MGPNP). Moss sampling was conducted using a purposive sampling technique along the Cibeureum waterfall route in the Halimun Camping Ground, Selabintana Resort, Mount Gede Pangrango National Park. Sampling was performed using a transect technique at five observation points of the waterfall path (2.6 km) (Figure 1), each with a transect line 200 m in length. At each point, host trees with a diameter at breast height (1.3 m) greater than 20 cm were selected. On each host tree, three 20 cm × 20 cm plots were established at heights ranging from 0 to 200 cm above the ground. Within each plot, all moss material and a small portion of the underlying substrate (rock, wood, or soil) were collected. Samples were collected directly and placed in zip-lock plastic bags and labeled for temporary identification.

Morphological identification of moss was carried out at the Laboratory of Plant Structure and Development, Jakarta State University. Identification was carried out using the Species Identification Sheet. The moss that had been collected was identified based on its morphological characteristics, including color, leaf shape, leaf tip, leaf base, leaf edge, and leaf arrangement. Morphological observations were carried out with the help of a light microscope and a stereo microscope. The morphological data obtained were then matched with the identification book. Furthermore, the classification of the moss was determined.

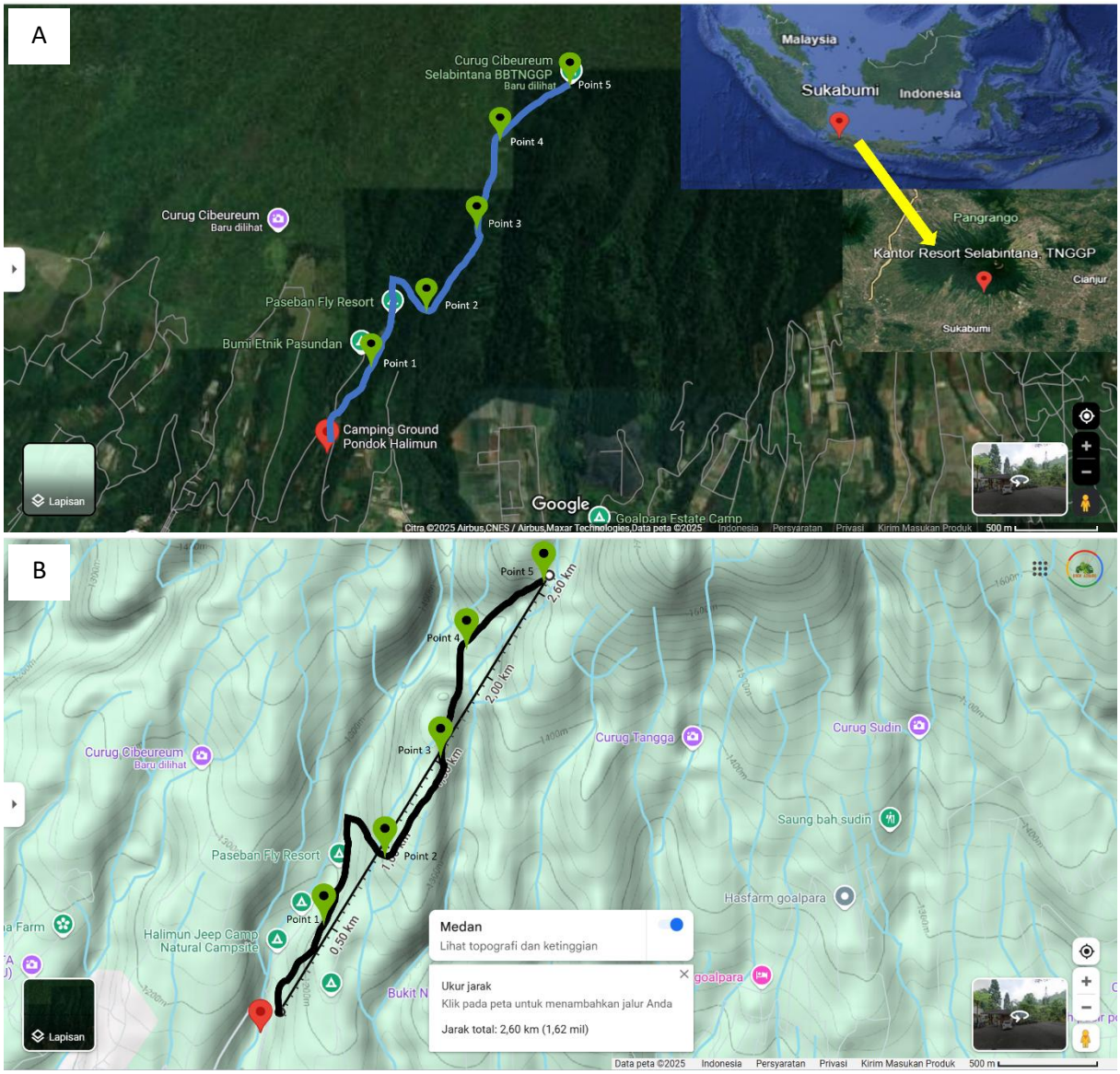

Figure 1. Map of moss exploration locations in Selabintana Resort, Mount Gede Pangrango National Park. (A) Satellite map and (B) Contour map from Google Maps Platform.

RESULTS

Moss exploration followed the Cibeureum waterfall path at the Selabintana Resort of Mount Gede Pangrango National Park (MGPNP), Sukabumi, West Java. A total of 23 species of moss (Table 1) were found from the divisions Bryophyta (leaf moss/true moss), Hepaticophyta (liver moss), and Anthocerohyta (horn moss) (see Figure 2 and 3).

Table 1. Species of moss in the Halimun Camping Ground area, Selabintana Resort, Mount Gede Pangrango National Park (MGPNP)

Divisi	Class	Family	Species	Substrat
Bryophyta	Bryopsida	Dicranaceae	*Dicranum scorpium*	Stone
		Bryaceae	*Amblystegium* s.	Leaves
		Mniaceae	*Rhizomnium punctatum*	Stem
		Hypnaceae	*Hypnum* sp.	Stem
		Thuidiaceae	*Thuidium tamariscinum*	Stone
		Bryaceae	*Bryum radiculosum*	Stone
		Hypnaceae	*Hypnum* sp.	Stone
		Octoblepharaceae	*Octoblepharum albidum*	Stone

Divisi	Class	Family	Species	Substrat
		Bryaceae	*Bryum apiculatum*	Stone
		Dicranellaceae	*Dicranella cerviculata*	Stone
		Pylaisiaceae	*Calliergonella cuspidata*	Stone
		Bryaceae	*Amblystegium serpens*	Leaves
		Fissidentaceae	*Fissidens taxifolius*	Stone
		Pottiaceae	*Hyophila involuta*	Stone
		Bryaceae	*Bryum capillare*	Stone
		Plagiotheciaceae	*Myurella julacea*	Stone
	Polytrichopsida	Polytrichaceae	*Polytrichum* sp.	Ground
		Polytrichaceae	*Pogonatum cirratum*	Stone
Marchantiophyta	Marchantiopsida	*Marchanti*aceae	*Marchantia* sp.	Ground
		*Marchanti*aceae	*Marchantia polymorpha*	Ground
		*Marchanti*aceae	*Marchantia* sp.	Ground
	Jungermanniopsida	Lophocoleaceae	*Heteroscyphus fissistipus*	Stem
Anthocerotophyta	Anthoceropsida	Notothyladaceae	*Phaeoceros minutus*	Stone

DISCUSSION

The diversity of moss species at this research location can be said to be quite diverse, and this diversity can be caused by various external factors, one of which is temperature. Selabintana Resort, Mount Gede Pangrango National Park (MGPNP) records temperature range of 18°C to 25°C and humidity is about 80-90% (Wasis *et al*., 2023) align with the optimal conditions for moss growth as noted by Tamaela *et al*. (2020), thereby supporting the dominance of Bryopsida species observed in this study. Moss plants usually live in humid places so that the temperature is usually at a low degree, at an average temperature of 10-30°C, many types of moss grow in that place. In addition, humidity also supports the growth of moss. In general, moss requires relatively high humidity to support its growth. Moss can live in a humidity range of 70-98% (Tamaela *et al*., 2020).

Similar studies have demonstrated that moss diversity is significantly influenced by microclimatic conditions. Research in other tropical regions has shown that areas with stable, high humidity and moderate temperatures support a greater variety of moss species (Gradstein *et al*., 2001). This aligns with the conditions observed at Selabintana Resort, suggesting that the microclimate of MGPNP provides an optimal environment for moss diversity. Beyond temperature and humidity, factors such as light intensity, soil pH, and substrate type play crucial roles in moss distribution. Shaded areas with acidic substrates often harbor unique moss communities (Glime, 2017b). The specific microhabitats within MGPNP, including shaded forest floors and moist rock surfaces, likely contribute to the observed moss diversity.

This study primarily focuses on temperature and humidity, potentially overlooking other influential factors like soil composition and light availability. Additionally, seasonal variations were not extensively studied, which could affect moss diversity and distribution. Future studies should adopt a holistic approach, examining multiple environmental variables and their interactions. Long-term monitoring would provide insights into temporal changes in moss communities, aiding in the development of conservation strategies.

Mosses are vital components of forest ecosystems, contributing to soil formation, nutrient cycling, and water retention. Their presence indicates healthy, undisturbed habitats. Protecting moss-rich areas like MGPNP is essential for maintaining overall forest health and biodiversity (Frahm, 2003). Mosses have applications in bioindication, horticulture, and even medicine. Their sensitivity to environmental changes makes them excellent bioindicators for monitoring ecosystem health (Richardson, 1981). Understanding the diversity at MGPNP could lead to discoveries of species with unique properties beneficial to these fields.

The moss species found in Halimun Camping Ground show clear substrate preferences—stone, stem, leaves, and ground—reflecting adaptations to diverse microhabitats (Table 1). Stone was the most common substrate, supporting resilient species like *Dicranum scoparium* and *Hyophila involuta*, which thrive in moist, low-organic surfaces (Ariyanti & Sulistijorini, 2011). Stem-dwelling mosses such as Hypnum sp. and *Thuidium tamariscinum* indicate epiphytic habits reliant on bark moisture and canopy litter (Siregar *et al*., 2023). Ground species like *Marchantia polymorpha* adapt to rich, moist soil, while leaf colonizers like *Amblystegium serpens* occupy short-lived, damp substrates. This pattern underscores the site's microhabitat complexity and bryophyte diversity.

Figure 2. Morphological various species of moss in the Halimun Camping Ground Area, Selabintana, Mount Gede Pangrango National Park (MGPNP) (a). *Dicranum scorpium* (b). *Amblystegium* sp. (c). *Rhizomnium punctatum* (d). *Hypnum* sp. (e). *Thuidium tamariscinum* (f). *Bryum radiculosum* (g). *Hypnum* sp. (h). *Octoblepharum albidum* (i). *Bryum apiculatum* (j). *Dicranella cerviculata* (k). *Calliergonella cuspidata* (l). *Amblystegium serpens* (m). *Fissidens taxifolius* (n). *Hyophila involuta* (o). *Bryum capillare* (p). *Myurella julacea* (q). *Marchantia* sp. (r). *Marchantia polymorpha* (s). *Marchantia* sp. (t). *Polytrichum* sp. (u). *Pogonatum cirratum* (v). *Heteroscyphus fissistipus* (w). *Phaeoceros laevis*

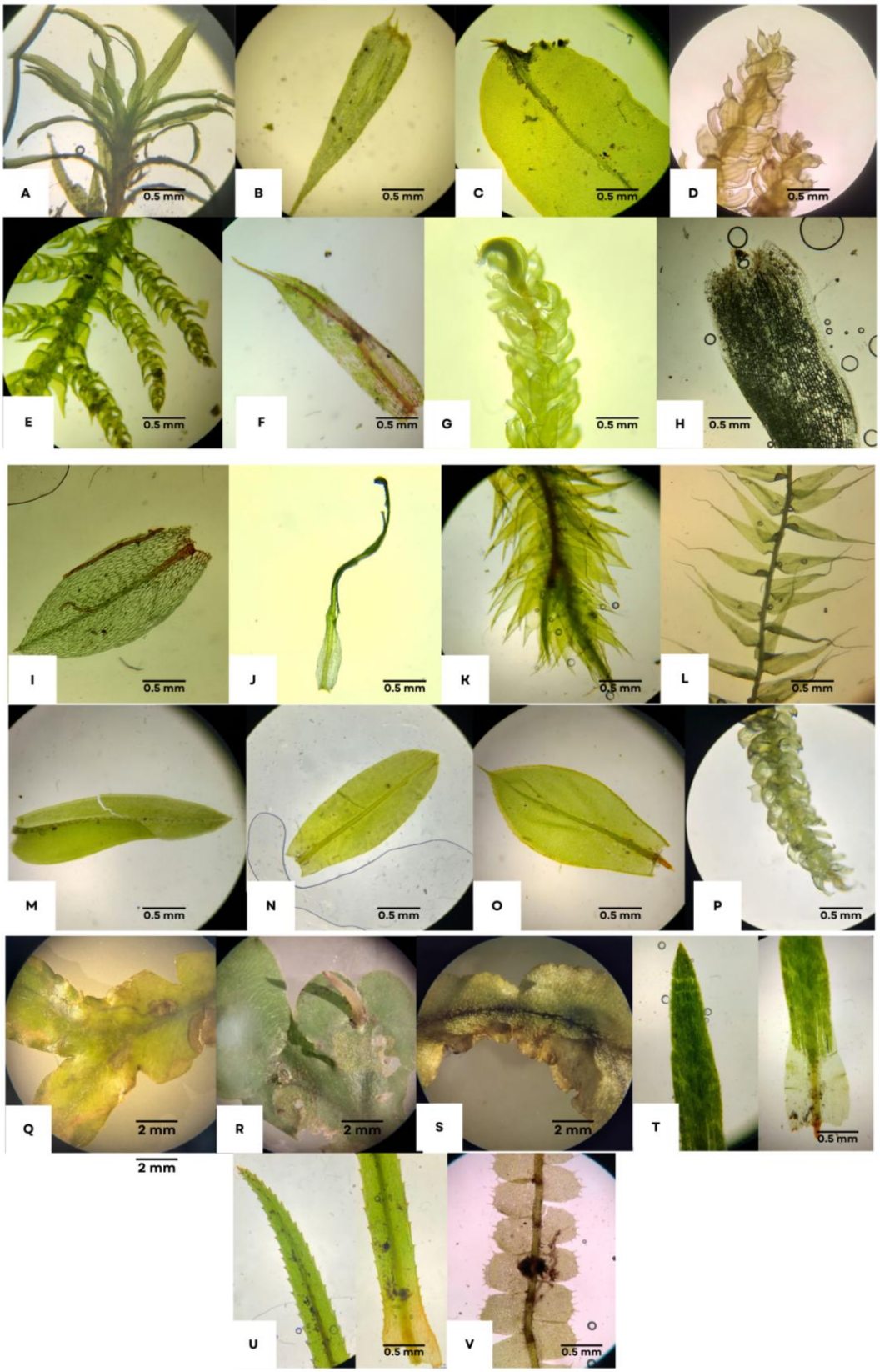

Figure 3. Leaf Structure of Moss Species (a). *Dicranum scorpium* (b). *Amblystegium* sp. (c). *Rhizomnium punctatum* (d). *Hypnum* sp. (e). *Thuidium tamariscinum* (f). *Bryum radiculosum* (g). *Hypnum* sp. (h). *Octoblepharum albidum* (i). *Bryum apiculatum* (j). *Dicranella cerviculata* (k). *Calliergonella cuspidata* (l). *Amblystegium serpens* (m). *Fissidens taxifolius* (n). *Hyophila involuta* (o). *Bryum capillare* (p). *Myurella julacea* (q). *Marchantia* sp. (r). *Marchantia polymorpha* (s). *Marchantia* sp. (t). *Polytrichum* sp. (u). *Pogonatum cirratum* (v). *Heteroscyphus fissistipus*

Description of Moss Species

Hyophila involuta

Hyophila involuta is included in the Bryophyta division with its morphology forming a thallus that resembles a leaf. Macroscopically (Figure 2.n), the stem is unbranched, creeping, with an upright shoot. The leaves are arranged in a spiral rosette, green in color, oval spathulate in shape, the base is attached to the stem with an acute tip. When dry, the leaves will be twisted. The sporophyte phase is located terminally, with setae that grow upright, long, and yellowish brown in color. It has no apophysis, the theca is oval in shape with a brownish color, the operculum has a tapered tip with a yellowish brown color. Microscopic observation (Figure 3.n) shows the leaf part with a small serrated edge. The center of the leaf has a costa with a percurrent shape. The cells at the base are larger in size and are rectangular or pentagonal in shape that are tightly arranged with each other. Apart from the base of the leaf, other parts of the leaf have smaller cell sizes and have more chlorophyll pigments.

Printarakul & Jampeetong (2021), described the morphology of *Hyophila involuta* moss with morphological characteristics of spathulate-lanceolate leaves with serrated to denticulate leaf edges that are very involute when dry, prominent mammillose upper laminal cells, well-differentiated leaf bases, costae with two well-developed stereid bands in cross-section, stems with well-differentiated central strands, and cylindrical eperistomate capsules. Meanwhile, Sawangproh (2024), described the morphology of *H. involuta* in the gametophyte phase has sizes ranging from 3.0 to 6.0 mm. Leaf shape lingulate to spathulate, leaf margin usually remotely and irregularly dentate at upper margin, leaf apex broadly acute to obtuse, usually with a distinct mucro, leaf costa strong, with brownish or reddish color, ending in the leaf tip. Capsule frequently present, cylindrical, urn-shaped, with a length of 2.3 mm. Seta up to 150 mm long, smooth, with red-brown color at the base, and pale above. This moss grows on microhabitat on humid silt and rocks on stream banks below 2500 m.

Ecologically, *H. involuta* was found growing on compact soil and rock surfaces in exposed, sunlit areas, confirming its adaptation to high light intensity and drought. These traits support its application in ecological restoration. This moss is also known for medicinal use in treating coughs and as a decorative plant in terrariums. Furthermore, it serves as a bioindicator and bioaccumulator of heavy metals (Abhliash & Alen, 2022) such as cadmium, zinc, and lead (Phaenark et al., 2023). Phytochemical studies show that *Hyophila involuta* moss contains alkaloids, cardiac glycosides, flavonoids, and saponins so that it can be used as an antimicrobial *against Candida albicans, Aspergillus flavus, Staphylococcus aureus*, and *Escherichia coli* (Makinde *et al*., 2015).

Marchantia polymorpha

The *Marchantia polymorpha* moss that we found was in the sporophyte phase. Morphological observations (Figure 2.r) showed that the thallus of *Marchantia polymorpha* was in the form of flat leaf sheets. The tips are lobed, the lower part has rhizoids in the form of thin fibers with a light brown color. The upper part of the leaf has a gemma cup with a bowl-like shape. Female spores, with archegoniophores growing upwards, are cylindrical, and have a light green color. The archegonium looks like a flower. Solihat & Kurnia (2021), described the morphology of *Marchantia polymorpha* as having a green thallus, with a hexagonal pattern on the upper surface (Figure 3.r). While the lower part has rhizoids that are useful for attaching to the substrate. The shape of the rhizoids resembles the roots of vascular plants. The tip and base of the thallus are blunt or flat, the tips are wavy and branched. The thallus is thick and has a stiff texture.

Secondary metabolites produced by *Marchantia polymorpha* include *Marchanti*n, flavonoids, phenols, and bibenzyls which have antimicrobial and antifungal activities. This moss has antioxidant, muscle relaxant, cardiotonic, anti-inflammatory, anti-cancer, hepatoprotective, and other therapeutic activities. In addition, this moss also contains cathepsin which inhibits osteoporosis (Purkon *et al*., 2022). Wang *et al*. (2016) mentioned that the potential of natural products, particularly extracts from the archegonium stem of *Marchantia polymorpha*, is crucial in developing effective acetylcholinesterase (AChE) inhibitors, which offer a promising avenue for therapeutic intervention in neurodegenerative conditions such as Alzheimer's disease.

Pogonatum cirratum

Pogonatum cirratum moss is a moss from the Bryophyta division. The gametophyte morphology *(Figure 2.u)* of this moss has a stem that grows upright, long, and does not branch. The leaves are attached to the stem, green, lanceolate in shape, with pointed tips and curved upwards. When dry, it will be twisted and change color to brown. Microscopic morphology (Figure 3.u), it can be seen that the

leaves of this moss have serrated edges. The middle part of the leaf has an excurrent costa, with the upper surface of the tip of the costa having serrations.

Bell & Hyvonen (2010), described the morphology of *Pogonatum cirratum* found in Kinabalu. *Pogonatum cirratum* moss is medium-sized, loose caespitose, with a dark green color. The stem is densely dendroid above, upright, and can reach 45 mm in height. The leaves are clustered, and when dry, they will shrivel. The fresh condition of this moss has leaves that are spread and upright, in the form of narrow-lanceolate lines. The leaf length is 5-6 mm and the width is 0.5-0.6 mm which narrows at the tip. Costa is an excurrent shape, with light brown color. Apical costa is serrated sharply with serrations on the back. *Pogonatum cirratum* contains abundant phenolic and flavonoid compounds which have antioxidant activity. The antioxidants produced by this moss are able to ward off free radicals (Mohandas & Kumaraswamy, 2018). *Pogonatum cirratum* moss can be used in research, one of which is to study stress response. This is done by testing the performance of PSII and photophosphorylation, photosynthetic carbon assimilation and carbohydrate synthesis, and its metabolism (Liu *et al*., 2017).

Bryum capillare

The *Bryum capillare* that we found was in the gametophyte phase. The morphology (Figure 2.o) of this moss has thin reddish brown rhizoids. The stems grow upright and are dark brown. The leaves are attached to the stem, arranged tightly with a spiral rosette position, from the air it looks like a star. The color of the leaves is green and will turn brown when old. The shape of the leaves is obovate, when old, the leaves will wrinkle. Observations under a microscope (Figure 3.o) show the morphology of *Bryum capillare* has a costa in the middle of the leaf. The tip of the leaf is filiform. The edge of the leaf at the tip has small, short serrations. The shape of the cells at the base is an irregular pentagon or rectangle, and is larger in size. While the cells in the middle to the tip of the leaf have a hexagonal shape that is arranged regularly.

Syed (1973), described the morphology of *Bryum capillare* with tufted morphological characteristics. Rhizoids are brown, dark reddish brown, and have papillosa. The rhizoid part sometimes has tubers with the same color as the rhizoids. Tubers can be round or irregularly oval. The leaves of this moss are arranged in a spiral with a close to loose distance. The leaf texture is soft, obovate-spatulate, the leaves can be flat or form a depression. The tip of the leaf is piliferous, the leaf edge is finely serrated at the tip or can also be on the entire edge. The basal cells are rectangular, rhombic-hexagonal, and thin-walled. Perichaetiale leaves, narrow lanceolate with long hairy tips.

Onbasli & Yuvali (2021) stated that *Bryum capillare* moss has the ability to synthesize aromatic substances, such as phenolics and nitrogen containing various vitamins, terpenoids, and other endogenous metabolites. The test results also showed antimicrobial, antibiofilm, antioxidant, antigenotoxic, and anti-cancer activities. In addition, *Bryum capillare* also has the ability as a bioindicator as well as an absorber of air pollution and heavy metals. Some of the heavy metals accumulated by this moss are iron, manganese, zinc, nickel, chromium, copper, and cadmium (Batan *et al*., 2021).

Myurella julacea

The *Myurella julacea* species has a long stem that grows creepingly or upright and branches. The leaves cover the stem in a dense arrangement, shaped like an ovoid or oval-ovoid. The fresh leaves are green, while when dry the leaves are brownish yellow (Figure 2.p). Microscopic morphology (Figure 3.p) shows leaves with blunt, rounded or slightly tapered tips. The edges of the leaves are flat.

Gao & Cao (1992), described the moss *Myurella julacea* as having a morphology with a green color, and when dry it will change color to yellowish. The stems are creeping or crowded and upright. The branches are irregular, the shape of julaceous branches, often with many rhizoids. The leaves are imbricate, concave, oval or oval-ovate. The length of the leaves is 0.4-0.5 mm with a width of 0.3-0.4 mm. The tip of the leaf is blunt, sometimes slightly tapered short. The edges of the leaves are flat with a very short costa.

Myurella julacea moss provides benefits in the field of plant genetics. Through genome analysis of *Myurella julacea* chloroplasts, information can be obtained for phylogenetic studies and the evolution of endangered moss (Han *et al*., 2020). *Myurella julacea* can grow in fairly dry environments, and has a high adaptability to various environmental conditions, even in the Arctic (Humlum *et al*., 2005). Currently, research on *Myurella julacea* is very limited, further research is needed to determine the benefits of this moss.

Polytrichum sp.

The *Polytrichum* sp. that we found was in the sporophyte phase. Morphological observations (Figure 2.t) showed that the thallus of *Polytrichum* sp. grows tall and upwards. The stem of this moss is relatively long and dark brown in color. The leaves are attached to the stem, arranged tightly with a spiral rosette position. This moss has relatively long lanceolate leaves, pointed leaf tips, and is dark green in color. Microscopic observations (Figure 3.t) showed that *Polytrichum* sp. moss has a leaf structure in the form of cells that are oval, tight, and contain green chloroplasts. There is a relatively thick and dark brown costa, a dark green lanceolate lamina, the leaf edges are relatively more pointed at the tips of the leaves, and have a light brownish green color. According to Retnowati (2019), *Polytrichum* sp. tends to be large, grows tall and dense. Leaves are usually divided into basic leaves with narrow costa and branch leaves with wide costa. This moss has partially or completely toothed edges. It has an upright, cylindrical capsule with a brownish calyptra.

Polytrichum sp. has practical applications, such as being used as pillow filling due to its soft and dense structure. It also contains bioactive compounds, including polyphenols, which exhibit antimicrobial properties (Lukitasari, 2018). These properties make it a potential candidate for natural antimicrobial agents. Additionally, its dense growth habit contributes to soil stabilization and moisture retention in its natural habitat, highlighting its ecological importance.

Thuidium tamariscinum

Thuidium tamariscinum moss is included in the Bryophyta division with its morphology forming a thallus that resembles leaves. Macroscopically (Figure 2.e), this moss has a distinctive appearance, namely dark green with a soft and dense texture. The stems of this moss are brownish green, have many branches, and are covered with dense leaves that are stacked on top of each other and opposite each other. Microscopically (Figure 3.e), *Thuidium tamariscinum* has lanceolate leaves with pointed tips and toothed edges. The cells in the leaves are clearly visible in the form of dense green circles. According to Alam *et al*. (2012), *Thuidium tamariscinum* has distinctive characteristics as pleurocarpous moss, namely yellowish green or dark green shoots. This moss is usually trifoliate, with green or reddish-brown stems covered with small branching filaments and very wide. The leaves are pointed, with the branchlets narrower and shorter. The branches of this moss are arranged in a plane and become shorter towards the end of the shoot. Capsules are rare, the gametophyte phase is more common. *Thuidium tamariscinum* has strong antioxidant activity and has great potential for use in medicine (Aslanbaba *et al*., 2017).

Bryum radiculosum

Bryum radiculosum forms dense, glossy dark green clumps or cushions, with densely growing shoots. The prominent, elongated veins at the leaf tips make the leaves (1.5–2.25 mm) appear straight (Figure 2.f). *B. radiculosum* has very small, round, reddish-brown rhizoidal tubers, but are usually only visible with a microscope (Figure 3.f). Capsules are about 3–5 mm long, common, and form in early summer. They hang down, becoming almost horizontal when mature. The moss often grows in dense clumps, up to 8 mm high; stem branched or unbranched; leaves imbricate when dry, erect to erect-patent, ± concave when wet; leaf shape ovate, elongated triangular, oblong to ovate-lanceolate, measuring 0.7-1.4 mm long and 0.25-0.4 mm wide; costa strong, slightly elongated at smooth arista; leaf margin ± curved upward, ± serrated at tip, smooth below; upper lamina cells smooth, thickened, 10-15 µm wide and (30-) 40-50 (-55) µm long; rhizoids yellowish brown, with dense coarse papillae; rhizoid gemmae abundant, reddish to yellowish brown, ± round, smooth surface (not protruding), with a diameter of 110-170 µm (Taha & Abou-Salama, 2020). The lichen *Bryum radiculosum* (Brid.), a species typical of dry and coastal environments, was used as a bioindicator to estimate the atmospheric deposition of trace metals around the industrial area of Portoscuso (Sardinia, Italy), which includes a lead-zinc smelter, two power plants and an aluminium production plant (Schintu *et al*., 2005).

Hypnum sp.

Hypnum sp. was found in the gametophyte phase and had a pine tree substrate. *Hypnum* sp. moss is dark green, the thallus stalk is long and branched, the thallus is arranged very tightly, short, flat edges, with a round apical tip (Figure 2.d). *Hypnum* sp. has various sizes, the thallus is yellowish green to brownish green. The thallus grows irregularly branched, upright, the part resembling a lanceolate leaf shape, with serrated leaf edges, and pointed leaf tips *(Figure 3.d)* (Indriyani, 2024). Historically, *Hypnum* sp. moss was used to fill beds because it was mistakenly believed to have properties that could

cause drowsiness. CityTree air filters, which are found in many cities in Europe, use *Hypnum* moss to capture pollutants (Petkova *et al*., 2022).

Bryum apiculatum

This moss grows as a low open bed or stem scattered among other mosses, dull green to brownish or reddish in color (Figure 2.i). The stem is 4–10 mm tall, the older parts are dull orange to reddish brown and often branched. The leaves are evenly arranged, not forming a rosette, with a distance wide enough so that the stem is visible. The leaves are ovate-lanceolate, erect, and do not change much when dry, with entire or slightly serrated edges (Figure 3.i). Costa is strong and green to brownish. Rhizoids are brown and papillated (Holyoak, 2009). Body length 3.4–4 mm, acrocarpous, with a living form resembling a mat. The stem forms a rosette and is light green. The leaves are lanceolate, bright green, 0.6–1.5 mm long and 0.2–0.4 mm wide. The leaf tip is tapering with a hairy tip 168.3 µm long. The leaf edge is flat from base to middle, sometimes finely serrated at the tip. Leaf cells are rhomboid, 59–60 µm long and 13–14 µm wide. Rhizoids are branched and red in color (Tsabituddinillah *et al*., 2023). There is no further information regarding the use of this moss.

Octoblepharum albidum

Octoblepharum albidum moss has scattered leaves. The thallus is pale whitish green, thick, and stiff with flat edges and leaf tips that vary from blunt to pointed. This moss grows on trees and has upright capsules with pointed tips, green to brown in color (Christanty, 2022). According to Santos & Stech (2017), *Octoblepharum albidum* is classified as a leaf moss from the Octoblepharaceae family. The morphology of this moss includes a spreading leaf arrangement, pale whitish green, thick, flat-edged, and pointed leaf tips (Figure 2.h). It is about 2 cm high with upright clump growth that forms a cushion. The stem is 1-1.5 cm high and grows upright. This moss is usually found attached in colonies to the trunks and roots of oil palm trees, spreading at the bottom of the tree trunk. This greenish-white epiphyte forms a dense mat on tree trunks with short stems, dense, stiff leaves that usually form a rosette at the tip of the plant. The leaves are ribbon-shaped with a pointed tip and are slightly finely serrated. The wide costa forms most of the leaf, with rows of chlorocysts and leukocysts in the center of the leaf. The setae are straight, measuring 0.4-0.5 mm, and the capsules are oblong-ovoid with cap-shaped calyptra (Figure 3.h). The spores are light brown, finely papillated, 20.5-22.0 µ in diameter (Cairns *et al*., 2020). *Octoblepharum albidum* generally lives attached to trees. The leaves of this moss appear thick and shiny. This moss is light green to pale green in color, with leaflets arranged in a linear shape. The stem is not visible because it is covered by leaves. The rhizoids are thread-like and firmly attached to the substrate. In the field, only the sporophyte phase is found, but according to, the *Octoblepharum albidum* moss has long setae and oval-shaped capsules that turn shiny brown when ripe (Amalia *et al*., 2024). In Indian folklore, extracts of the *Octoblepharum albidum* moss are used for the treatment of fever, bacterial infections, and diabetes. *O. albidum* has the ability to fight diabetes by specifically working against digestive enzymes (Tatipamula *et al*., 2021).

*Marchanti*a sp.

This moss has a green thallus with a hexagonal pattern on the upper surface. The lower part of the thallus has many rhizoids that function to attach to the substrate, similar to the roots of vascular plants. The tip and base of the thallus are blunt or flat, with wavy and branched tips, and a thick and stiff thallus. The surface is smooth, has black lines, and many pores (Figure 2.s). There are two reproductive organs, namely antheridium and archegonium. Antheridium is cup-shaped with a flat surface and short margins, up to 1 cm long. Archegonium is radial and spreading, reaching a length of 1.2 cm. In addition to sexual reproduction through spores, *Marchanti*a sp. also reproduces asexually with lentil-shaped gemmae that are released through water droplets from the gemmae cup (Solihat & Kurnia, 2021). *Marchanti*a is a genus of liverworts that can be easily found throughout the world. In recent years, global research has been conducted on *Marchanti*a species. *Marchanti*a species in various classical Greek medical references/records have been used as valuable plants for open wound healing applications as prevention of bacterial infections, inflammatory wounds, external wounds, anti-snake venom, and treatment for liver dysfunction (Purkon *et al*., 2022).

Phaeoceros laevis

Phaeoceros laevis is included in the hornwort species with a flat, greenish thallus, ±5 cm long, ±2 cm wide, and ±0.5 mm thick. The thallus has a smooth surface, does not have a leaf vein, and the apex

is rounded or truncated. This moss has a capsule that rises high upwards, is ±7 cm long, and is predominantly green with a brownish yellow capsule tip. *Phaeoceros laevis* moss has a thallus that is similar to leafy liverworts (Figure 2.w). The surface of the thallus is smooth, dark green, and has a capsule that resembles a horn (Ristanto *et al.*, 2021). According to Mundir *et al*., (2013), *Phaeoceros laevis* has a talus forming a cluster, has no midrib, and its branching is forked. The elongated capsule is cylindrical, perpendicular to the talus. The tip of the capsule splits into two halves when mature.

Dicranum scorpium

Dicranum scorpium is a moss that is classified as a leaf moss. This moss has tassel-shaped leaves with leaf sheaths that extend to the tip and have protrusions along the back of the leaf (Figure 2.a). The leaves of this moss are spear-shaped with long, slender tips. The leaves are dark to light green but can turn brown when dead or in dry conditions and most of the leaves are folded to one side and wavy (Figure 3.a). *Dicranum scorpium* has sporophytes with long setae (stalks) and elongated capsules. These capsules contain spores that are released for reproduction. The capsules are usually upright, but can be slightly tilted. As a moss, *Dicranum scorpium* plays an important role in its ecosystem, including in the process of decomposition and humus formation. This moss also functions as a ground cover that helps reduce erosion and maintain soil moisture (Karaoğlu *et al*., 2022).

Rhizomnium punctatum

Rhizomnium punctatum has bright green leaves, elliptical to oval in shape with rounded tips. The leaves are arranged in a spiral on the stem and are firmly attached (Figure 2.c). *Rhizomnium punctatum* has an upright, unbranched thallus (main stem) with a height of about 1-3 cm. The stem is often reddish brown *(Figure 3.c)*. *Rhizomnium punctatum* has rhizoids protruding from the base of the stem, which help in the absorption of nutrients and water from the substrate. As an important component of the moss community, *Rhizomnium punctatum* plays a role in maintaining ecosystem humidity, helping the soil formation process, and providing habitat for microorganisms and small invertebrates (Bielańska-Grajner *et al*., 2017).

Amblystegium sp.

Amblystegium sp. has a slender, creeping thallus, and often forms dense colonies or mats on the surface of the substrate. The stem is golden brown to dark green, lanceolate to oval in shape with a pointed tip (Figure 2.b). These leaves are arranged in a spiral along the stem, with the leaves slightly curved downwards (Figure 3.b). Rhizoids in *Amblystegium* sp. develop from the lower part of the stem and function to attach to the substrate and absorb water and nutrients. These rhizoids are often reddish brown (Stark, 2017).

Dicranella cerviculata

Dicranella cerviculata usually grows to a height of 6 mm, forming a yellow-brown tuft. In some cases, sterile plants can reach up to 30 mm. The leaves are linear lanceolate, measuring about 2.5–3 mm long (Figure 2.j). The leaves are upright, spreading, and curved or slightly curved, with a slender and pointed or blunt apex. The leaf margin is generally entire but may be slightly serrated near the tip. The costa (midvein) extends almost to the tip of the leaf, occupying about half the width of the leaf base. This species is dioecious, meaning that each plant is either male or female. The seta, or stalk that supports the capsule (Figure 3.j), is usually 5–6 mm long, initially yellow, and turns brown when mature. The capsule itself is 0.7–1 mm long, nodular, curved, asymmetrical, and grooved (having a swollen base). The capsule becomes grooved when dry. The peristome teeth, which aid in spore dispersal, are 270–350 µm long and distally divided. The spores are 16–21 µm in diameter, ranging from smooth to slightly rough (Fedosov *et al*., 2023). Ecologically, *Dicranella cerviculata* plays an important role as part of the moss community in humid forests. This moss contributes to water retention, helps prevent soil erosion, and serves as a habitat for microorganisms. In addition, this moss can serve as an environmental indicator due to its sensitivity to changes in humidity and air quality.

Calliergonella cuspidata

Crawling and branching stems, often forming dense mats. The stems are bright green to dark green (Figure 2.k), about 5-10 cm long. The leaves are narrow lanceolate to triangular-lanceolate, with a sharply pointed tip (cuspidate). The leaves are densely arranged and tend to curve outwards, giving a regular appearance. The setae are long and erect (Figure 3.k), reddish in color. The capsules are

cylindrical or elongated, often hanging with a conical operculum, and have a double peristome for spore dispersal (Glime, 2017a). *Calliergonella cuspidata* plays an important role in water retention and erosion prevention in wet habitats. This moss also supports biodiversity by providing habitat for microorganisms and invertebrates (Rydin & Jeglum, 2013).

Amblystegium serpens

Amblystegium serpens is a widespread leafy moss found in a variety of habitats, including forests, riverbanks, rocks, and moist soils. Creeping or trailing, with smooth, slender branches. The stems are usually small, about 1-5 cm long, and green to greenish brown (Figure 2.l). The leaves are small, narrow, and lanceolate to linear, with a tapering tip. The leaves are arranged spirally along the stem, with smooth or slightly wavy margins. The leaf cells are long and narrow, with thin walls. The leaves usually have a single midrib (costa) that does not reach the leaf tip (Figure 3.l). The seta (sporophyte stalk) is short to medium in size, yellow or brown in color. The capsules are cylindrical to slightly curved, with a small, cone-shaped operculum. The capsules are often oblique and have a double peristome that helps in spore dispersal (Glime, 2017b). *Amblystegium serpens* plays an important role in the ecosystem as a water absorber and erosion preventer. This moss helps maintain soil moisture and provides a habitat for various microorganisms. This moss is often used as a bioindicator of environmental conditions, especially in terms of humidity and air quality, because of its sensitivity to pollution and environmental changes. A. serpens is often used in habitat restoration projects, especially to restore disturbed areas such as riverbanks and degraded forests (Smith, 2004).

Fissidens taxifolius

Fissidens taxifolius is a moss belonging to the Fissidentaceae family, often found in moist habitats such as riverbanks, wet forests, and shaded soils. *Fissidens taxifolius* grows upright with a height of usually around 1-3 cm. The stem has a dense structure with leaves arranged in distichous pairs (in two opposite rows) (Figure 2.m). The leaves are lanceolate to ligulate, with blunt or slightly pointed tips. The leaves are arranged in two parallel rows on the stem, a characteristic of the genus Fissidens. These leaves also have flat edges with smooth margins (Figure 3.m). Leaf cells are square to elongated, with thin cell walls. The ribs (costa) are usually prominent and run almost the entire length of the leaf. The setae are short and erect, reddish or brown in color. The capsule is elliptical to cylindrical, with a conical operculum. Capsules often appear at the tips of stems or branches (Glime, 2017b).

Fissidens taxifolius plays an important role in the wetland ecosystem by helping to retain soil moisture and prevent erosion. This moss also provides microhabitats for various invertebrate species and microorganisms. Due to its sensitivity to environmental changes, *F. taxifolius* is often used as a bioindicator of air quality and environmental conditions, especially in areas affected by pollution. This moss is used in ecosystem restoration projects to help improve soil structure and enhance habitat quality, especially in degraded or disturbed areas (Frey & Kürschner., 2011).

Heteroscyphus fissistipus

Heteroscyphus fissistipus is a large genus of leafy liverworts with 34 representative species in Tasmania. Some species of this genus may be difficult to distinguish from the related Chiloscyphus and require examination of fertile material to confirm generic identity. Many members of this genus were formerly referred to as *Chiloscyphus*. Overall, many common *Heteroscyphus* species tend to be larger than those of *Chiloscyphus* and the leaves of the former are more consistently continuous with both sides of the lower leaf (Figure 2.v), although this character also occurs occasionally in *Chiloscyphus* (e.g. C. *leucophyllus*). More specifically, the gynes (female sexual organs) of *Heteroscyphus* always arise on short, specialized branches that arise from the sides of the shoot whereas those of *Chiloscyphus* arise mostly from unspecialized leaf tips (Figure 3.v). *Heteroscyphus* cells often have large trigones (cell wall thickenings) and granular oil bodies. This moss plays a role in maintaining ecosystem humidity, preventing soil erosion, and being a habitat for microorganisms. *Heteroscyphus fissistipus* also helps in water absorption and functions as an indicator of the health of a humid forest environment (Bakalin *et al*., 2020).

CONCLUSION

Based on the results of this study, it can be concluded that in the Halimun Camping Ground Area, Selabintana Resort, Mount Gede Pangrango National Park (MGPNP) there are 23 species of moss, some of which have not been identified to the species stage. The Bryopsida class is the most dominant

class compared to the others, namely there are 18 species of true mosses (Bryopsida and Polytrichopsida), 4 species of liver mosses (Marchantiopsida and Jungermanniopsida), and 1 species of horn moss (Notothyladaceae). According to various literature and scientific journal sources, moss has a variety of significant utilization potentials, both for environmental sustainability and meeting human needs. These funding of floristic studies of moss diversity in Halimun Camping, Selabintana Resort, MGPNP, suggest that further research be conducted on the role of mosses as a bioindicator, mosses response to climate change, and the role of mosses for human health

ACKNOWLEDGEMENTS

The authors express their sincere appreciation to Selabintana Resort, Gunung Gede Pangrango National Park (MGPNP), for the valuable support and assistance provided during the data collection process. We are also deeply grateful to the reviewers and editors for their constructive feedback, which significantly enhanced the quality of this manuscript.

CONFLICT OF INTEREST

There is no conflict of interest.

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