

## CONTRASTING ARBOREAL AND TERRESTRIAL BRYOPHYTES COMMUNITIES OF THE MOUNT HALIMUN SALAK NATIONAL PARK, WEST JAVA

NUNIK S. ARIYANTI and SULISTIJORINI

*Department of Biology, Faculty of Mathematics and Natural Sciences,  
Bogor Agricultural University*

Recipient of BIOTROP Research Grant 2009 / Accepted 30 April 2011

### ABSTRACT

Bryophyte communities were compared between arboreal (trunk bases) and terrestrial habitats in primary forest Mount Halimun Salak National Park, West Java. The communities were analyzed based on species diversity, abundance, and biomass. A total of 150 bryophytes species were identified, including 67 species of mosses (Bryopsida) and 83 of liverworts (Hepaticopsida). Both bryophyte groups varied in diversity and abundance between arboreal and terrestrial communities as well as among different elevations. Species diversity of arboreal habitats (116 species) was higher than that of terrestrial habitats (64 species). Moss species were more abundant in terms of coverage in terrestrial habitats whereas liverworts species were more abundant in arboreal habitats. Species richness in both terrestrial and arboreal habitats decreased towards higher elevation, whereas the abundance increased.

**Key words:** Bryophytes, mosses, liverworts, terrestrial habitat, arboreal habitat

### INTRODUCTION

Bryophytes are frequently neglected due to its small size and their economical value is not much known. However, a recent study (Harris 2008) listed about 150 ethnobotanical species of bryophytes; about 27 percent of those species are used in traditional Chinese medicine including *Rhododendron giganteum* which is used for treating nervous disorder and cardiovascular disease. This species is also found at Mount Gede Pangrango National Park (Hasan & Ariyanti 2004).

Bryophytes occupy a wide range of habitats, colonizing various terrestrial substrates, tree trunks and tree canopies. Bryophytes represent important components of forest floor and epiphyte communities in many ecosystems, contributing to forest diversity, structure and ecosystem-level processes. Even bryophytes especially liverworts are abundant and dominant in “cloud” or “mossy” forest.

---

Corresponding author : nuniksa@gmail.com

Despite of their traditional medicinal use, bryophytes have a range of important roles to play in the environment. Bryophytes may serve as substrate for other plants and offer shelter to small animals. Changes in epiphytic bryophyte assemblages affect other canopy dwelling biota, such as vascular epiphytes, invertebrates, and especially foraging birds (Sillet 1994; Andrew *et al.* 2003). The moist environment created by the bryophytes is also quite favorable to the establishment and growth of important groups of microorganisms, such as the nitrogen-fixing blue green algae (Gradstein *et al.* 2001). The abundance of liverworts in “cloud” or “mossy” forest is considered an important factor in eliminating the deteriorating effect of heavy rains, including helping to prevent soil erosion and adding to hill stability (Pócs 1980). Bryophytes may serve as potential indicators of climate changes since they are closely associated with climatically sensitive habitat and ecosystem (Gignac 2001). In addition, bryophytes have important contributions to forest nutrient cycling, particularly to N-cycling (Longton 1984; Turetsky 2003).

Structure and floristic composition in tropical rain forests vary considerable. The bryophyte flora of tropical rain forest changes significantly with elevation, different taxa often occur in the different forest belts. Bryophytes are very useful indicators of life zones and forest types in tropical mountain regions, since they have relatively modest number of species and genera, very wide geographical ranges, and great variation in biomass (Frahm & Gradstein 1991).

Studies dealing with diversity and abundance of bryophytes are more frequently referred to temperate region and tropical America region (e.g. McGee & Kimmerer 2002; Sillet *et al.* 1995; Acebey *et al.* 2003; Nöske *et al.* 2008) than to tropical Asia. Among a few ecological studies of bryophytes in tropical Asia (Frahm 1990; Sporn *et al.* 2009; Gradstein & Culmsee 2010) is the diversity and abundance of epiphytic bryophytes assessed in primary and secondary submontane rain forest and cacao agroforestry in Sulawesi (Ariyanti *et al.* 2008). However, the study did not simultaneously compare the community structures and contributions of both arboreal (epiphytic) and terrestrial bryophyte species in the same ecosystem.

Although Java was considered well inventoried, recent publications dealing with the bryophytes of Java are very few and a modern checklist for mosses is lacking. In contrast, checklists of both mosses and liverworts of others major islands in Malesian region (Borneo, Sulawesi, Philippines) have been provided (Ariyanti & Gradstein 2007; Ariyanti *et al.* 2009; Gradstein *et al.* 2005; Menzel 1988; Tan & Engel 1986; Tan & Iwatsuki 1991; Suleiman *et al.* 2006). Söderström *et al.* (2010) published a first modern checklist of the liverworts and hornworts of Java and reported more than 600 species for the island. Of these, 479 are accepted species as currently understood based on revision and monographs; the remaining species are little known or of doubtful status, or invalid names.

This research examines bryophyte communities in understory forest of Mount Halimun, West Java, Indonesia. Mosses of Mount Halimun have recently been inventoried (Tan *et al.*, Reinwardtia 12(3): 205-214. 2006) but liverworts and hornworts of the mountain have not yet been reported. There are two primary aims: to assess and compare bryophyte communities in two different substrate type (arboreal and terrestrial) and different altitudes of study sites.

## MATERIALS AND METHODS

### Study Area

The study took place at Mount Halimun which is located in Mount Halimun Salak National Park, West Java province, Indonesia 106°12' - 106°45' East, 06°32' - 06°55' South. The four study sites were established at different altitudes: at 1730 m (site 1), 1250 m (site 2), 1100.m (site 3) and 1000. m (site 4).

At each of the four study sites, a plot of 30 x 30 m was established. At each plot, terrestrial and arboreal bryophyte diversity were estimated based on species richness and abundance (cover cm<sup>2</sup> and frequency %); the total biomass of the several most dominant species were surveyed; the forest stand and vascular plant characteristics were inventoried. Field samplings were done between July and August 2009.

### Terrestrial Sampling

Methods for terrestrial diversity sampling referred to (Botting *et al.* 2008) with few modifications. At each plot of 30 x 30 m, two parallel 30 m transects were established 10 m apart, along which the bryophytes were surveyed in 1 x 1 m subplot placed at five equi-distant points on the transect. Each species present was recorded and collected for future identification; the coverage (cm<sup>2</sup> of cover) and frequency (%) of each species occurred in the subplots were recorded based on the quadrat 20 x 30 cm.

### Arboreal Sampling

Arboreal bryophytes were sampled on five selected trees per plot of 30 x 30 m following Ariyanti *et al.* (2008) and Botting *et al.* (2008) with modifications. Selected arboreal sampling trees supporting bryophytes are the trees of more than 20 cm of diameter breast high. Five quadrats of 20 x 30 cm<sup>2</sup> were placed at different directions of 0-200 m high of tree trunk. Each species present on the quadrat was recorded or collected for future identification. The coverage (cm<sup>2</sup> cover) and frequency (%) of the species in a quadrat of 20 x 30 cm<sup>2</sup> were also recorded.

### Data Analysis

Species identification was done using the following literature: Eddy (1988; 1990; 1996) and Bartram (1039) for the mosses, draft version of Gradstein (2011) for the liverworts. An Analysis of variance (ANOVA) with the main fixed effects of altitude (plots at different altitude) and substrates type (arboreal and terrestrial) were used to evaluate bryophyte communities in the understorey forest with respect to species richness, coverage.

## RESULTS

### Species Diversity

In total, 150 bryophytes species were identified across the terrestrial and arboreal (trunk bases) habitats in the primary forest of the Mount Halimun Salak National Park. They consist of 67 species of mosses (Bryopsida) and 83 species of

liverwort (Hepaticopsida). In this research we did not find any hornwort species (Antocerotopsida) in the plots. Hornwort commonly occurs in humid, non-forest terrestrial habitats such as river bank or the open slope of forest margins. Arboreal bryophytes with 116 species found on the base of tree trunks seems more diverse than those of terrestrial bryophytes with 64 species, identified from various substrates such as rotten log, root of trees, rock, and humus. Thirty three species were identified from both terrestrial and arboreal substrates. The lists of species found in the study sites is presented in Appendix 1.

**Species richness and abundance**

The total number of species found in the plots of 30 x 30 m ranged from 46 species in plot III to 79 species in plot IV. Species richness of arboreal bryophytes in the plots was higher than that of terrestrial bryophytes and varied from 38 to 64 (Fig. 1). Among the arboreal bryophytes, the number of liverworts species in each plot mostly was higher than those of mosses species. On the other hand, the terrestrial bryophytes composed of more mosses than liverworts species.

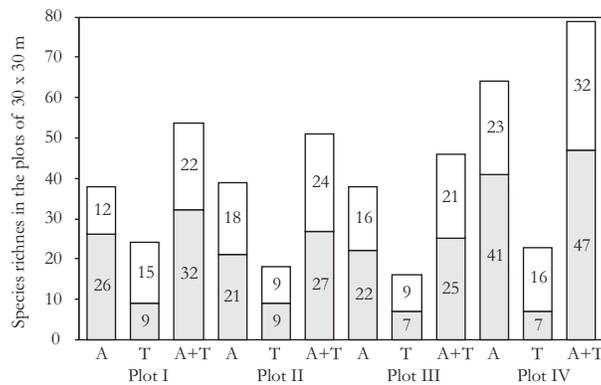


Figure 1. The species number of liverworts (■) and mosses (□) on arboreal (A) and terrestrial (T) substrates in plot I, II, III, and IV (30 x 30 m) that located at different altitudes

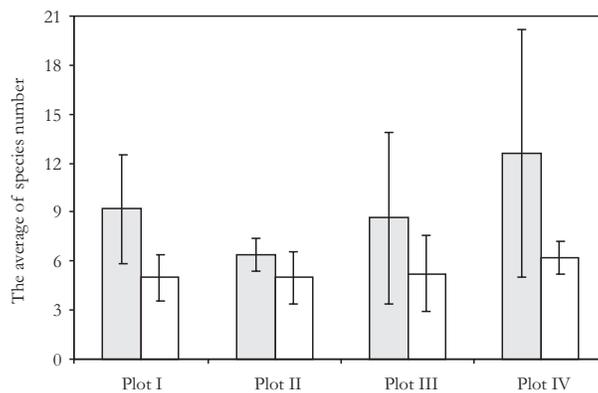


Figure 2. The average of species number of liverworts (■) and mosses (□) of arboreal bryophytes in each tree trunk base in plot (30 x 30 m) I, II, III, and IV

Table 1. The six highest coverage (cm<sup>2</sup>, ± standard error) of terrestrial and arboreal bryophytes species in quadrates of quadrat (20 x 30 cm) in plot I, II, III, and IV. See also Appendix 1.

Terrestrial bryophytes		Arboreal bryophytes	
Plot / Species	Coverage cm <sup>2</sup>	Plot / Species	Coverage cm <sup>2</sup>
<b>Plot I</b>		<b>Plot I</b>	
<i>Hypnodendron</i> sp. 1	60.1 ± 17.8	<i>Syrrhopodon tristichus</i>	119.7 ± 61.2
<i>Trismegistia regida</i>	48 ± 33.2	<i>Plagiobhila frondescens</i>	95.5 ± 52.4
<i>Bazzania</i> sp. 1	24.8 ± 15.5	<i>Schistochila sciurea</i>	95.3 ± 50.2
<i>Pogonatum macrophyllum</i>	24 ± 24.0	<i>Bazzania tridens</i>	94.4 ± 52.6
<i>Trichosteleum elegantissimum</i>	19 ± 14.0	<i>Plagiobhila dendroides</i>	85.3 ± 49.5
<i>Bazzania vittata</i>	18.0 ± 12.4	<i>Bazzania vittata</i>	81.2 ± 43.7
<b>Plot II</b>		<b>Plot II</b>	
<i>Calyscostella papillata</i>	58.6 ± 29.3	<i>Spruceanthus polymorphus</i>	21.4 ± 10.7
<i>Heteroscyphus argutus</i>	26.9 ± 15.66	<i>Plagiobhila sciophyla</i>	18.8 ± 12.4
<i>Lejeunea anisophylla</i>	18.6 ± 18.6	<i>Heteroscyphus argutus</i>	17.7 ± 9.6
<i>Telanarea neesii</i>	15.8 ± 10.9	<i>Escostratum blumei</i>	14.2 ± 13.5
<i>Vesicularia reticulata</i>	15.5 ± 9.2	<i>Leucophanes massartii</i>	14.2 ± 10.9
<i>Distichophyllum schmidtii</i>	11.8 ± 8.3	<i>Plagiobhila javanica</i>	12.2 ± 8.5
<b>Plot III</b>		<b>Plot III</b>	
<i>Calyscostella papillata</i>	65.8 ± 57.4	<i>Lejeunea anisophylla</i>	36.0 ± 18.2
<i>Heteroscyphus argutus</i>	30.8 ± 26.4	<i>Mitth yridium</i>	
<i>Acanthorrhynchium papillatum</i>	30.5 ± 18.4	<i>junquilianum</i>	28.9 ± 15.9
<i>Vesicularia reticulata</i>	24.3 ± 16.3	<i>Radula javanica</i>	20.0 ± 9.6
<i>Lejeunea anisophylla</i>	23.3 ± 18.4	<i>Mitthyridium flavum</i>	19.4 ± 10.1
<i>Telanarea neesii</i>	18.6 ± 15.5	<i>Acanthorrhynchium papillatum</i>	10.4 ± 7.0
<b>Plot IV</b>		<b>Plot IV</b>	
<i>Trichosteleum boschii</i>	33.1 ± 19.0	<i>Syrrhopodon muelleri</i>	19.6 ± 13.3
<i>Acanthorrhynchium papillatum</i>	31.7 ± 31.7	<i>Plagiobhila propingua</i>	14.5 ± 10.8
<i>Isopterygium albesce ns</i>	17.6 ± 12.5	<i>Thysananthus retusus</i>	13.9 ± 8.8
<i>Heteroscyphus argutus</i>	14.0 ± 7.1	<i>Radula javanica</i>	13.1 ± 8.8
<i>Isopterygium bancanum</i>	12.1 ± 9.0	<i>Pyrrobryum spiniforme</i>	12.7 ± 12.7
<i>Chaetomitrium lanceolatum</i>	6.5 ± 6.5	<i>Acroporium lamprophyllum</i>	9.4 ± 9.0

Bryophytes found at trunk bases (0-2 m) ranged from 11 to 28 species. Each tree trunk base mostly had more liverworts (6 - 13 species) than mosses (5 - 6 species) (Fig. 2). Though the difference was not significant (ANOVA, n=5, p=0.05), the number of liverworts and mosses in plot IV was slightly higher than those in other plots. On the contrary, plot II has lower species richness than the other plots.

Species abundance of bryophytes that were estimated based on bryophytes coverage on the substrate showed that the most dominant species of terrestrial bryophytes (indicated by high coverage) is mostly included in the group of mosses, whereas most of arboreal bryophytes having high coverage are the liverworts species. In common, coverage of arboreal species is higher than that of terrestrial species (Table 1).

Though species richness in the plot IV was higher than that of other plots, the coverage of species in plots IV was lower than those in other plots. The arboreal species with the highest coverage in plot IV is *Syrrhopodon muelleri* which covered about

Table 2. The species of arboreal and terrestrial bryophytes occurred at least 20% of sampled quadrates (n = 25) in plot I, II, III, and IV. See also Appendix 1.

Arboreal bryophytes		Terrestrial bryophytes	
Plot / Species	Frekuensi of occurrence (%)	Plot / Species	Frekuensi of occurrence (%)
<b>Plot I</b>		<b>Plot I</b>	
<i>Syrrhopodon tristichus</i>	80	<i>Hypnodendron</i> sp. 1	40
<i>Leucobryum javense</i>	40	<i>Trichosteleum elegantissimum</i>	24
<i>Bazzania vittata</i>	40		
<i>Plagiochila frondescens</i>	36		
<i>Plagiochilon oppositum</i>	36		
<i>Schistochila sci urea</i>	28		
<i>Plagiochila dendroides</i>	24		
<i>Radula javanica</i>	20		
<b>Plot II</b>		<b>Plot II</b>	
<i>Lejeunea anisophylla</i>	28	<i>Callyscostella papillata</i>	20
<i>Lopidium trichocladon</i>	24	<i>Heteroscyphus argutus</i>	20
<i>Heteroscyphus argutus</i>	24		
<i>Spruceanthus polymorphus</i>	24		
<i>Pinnatella</i> sp. 1	20		
<i>Radula multiflora</i>	20		
<b>Plot III</b>		<b>Plot III</b>	
<i>Lejeunea anisophylla</i>	44	<i>Trichosteleum boschii</i>	24
<i>Mitthyridium junquilianum</i>	24		
<i>Harpalejeunea filicuspis</i>	24		
<i>Lejeunea discreta</i>	24		
<i>Radula javanica</i>	24		
<i>Leucophanes octoblepharoides</i>	20		
<i>Mitthyri dium flavum</i>	20		
<i>Mitthyridium wallisii</i>	20		
<i>Thysananthus spatulistipus</i>	20		
<b>Plot IV</b>		<b>Plot IV</b>	
<i>Leucophanes octoblepharoides</i>	28	<i>Heteroscyphus argutus</i>	20
<i>Heteroscyphus argutus</i>	28		
<i>Schistochila aligera</i>	28		
<i>Cheilolejeunea ceylanica</i>	24		
<i>Acroporium lam prophyllum</i>	20		
<i>Leucophanes massartii</i>	20		
<i>Plagiochila bantamensis</i>	20		
<i>Radula javanica</i>	20		

20 cm<sup>2</sup> (3.3%) of the quadrats. The arboreal species with highest coverage is *Syrrhopodon tristichus* in plot I that covered 120 cm<sup>2</sup> (20%) of the quadrates. The six most abundant species in the plot I covered more than 80 cm<sup>2</sup> (13.3%) area of quadrate, whereas the six most abundant species in others plot cover less than 40 cm<sup>2</sup> (6.7%) of the quadrates (Table 1).

Distributions of species in the plots are mostly rare. Most species were found in only one of 25 sampled quadrates. Some species are found only twice and others more often in the quadrates (Appendix 1). Only two species were found in more than 10 quadrates. The common species found in at least 20% of the sampled quadrates are

listed in Table 2. Liverwort species are more numerous in the arboreal plots (16 species, of 26 species in total), whereas mosses are more numerous in the terrestrial plots (4 of 5 in total).

Among the species which have high frequency of occurrence is the epiphytic mosses *Syrrhopodon tristichus* in plot I which were found at twenty quadrates. The frequency of occurrence of the species is about 80 %. Other species were often found in the plot are *Leucobryum javense*, *Bazzania vittata*, (both species are epiphytic species in plot I) *Hypnodendron* sp. 1, and *Taxithelium isocladum* (both are terrestrial species in plot I and II respectively), all of those species have 40 % of the frequency of occurrence (Table 2).

## DISCUSSION

The bryophyte diversity at natural primary forest of the Mount Halimun Salak National Park Hutan is quite high, it comprises no less than 150 species found across the arboreal (trunk bases) and terrestrial habitats. The arboreal diversity is almost as high as in the submontane forest area of Lore Lindu National Park, Central Sulawesi, where Ariyanti *et al.* (2008) found about 169 bryophytes species on trunk bases in twelve plots. The slightly higher figure for Central Sulawesi is perhaps because the research in Central Sulawesi was conducted in three forest types (natural primary forest, secondary forest, cacao agroforest), while the present research was conducted in primary forest only.

The result of arboreal species (116 species) that were inventoried from 20 sample trees was higher compared with the number of species collected from fewer tree samples and reported for primary submontane (1100 m), lower montane (1400 m) and upper montane (3250 m) forest in Lore Lindu Park, Central Sulawesi, by Gradstein & Culmsee (2010). Having the same number of tree samples, Ariyanti *et al.* 2008 collected 112 species from primary submontane (1000 m) forest in Lore Lindu National Park. The arboreal diversity would have been much higher when the whole trees would have been inventoried. Sporn *et al.* (2009) collected more epiphytic species than Ariyanti *et al.* (2008) from the same locations studied by Ariyanti *et al.* (2008). However, Sporn *et al.* (2009) sampled the whole trees (the tree trunk and canopy).

When species richness of arboreal and terrestrial bryophyte are compared, the richness of terrestrial bryophytes is lower than that of arboreal species in all the plots. It is not in accordance with the richness of terrestrial bryophytes at the temperate spruce forest which species richness of terrestrial bryophyte exceeds those of arboreal bryophytes (Botting *et al.* 2008). Tropical rain forests are characterized by high diversity of big tree plants which offers various habitats for epiphytic bryophytes, it perhaps relates to the high diversity of arboreal bryophytes at tropical forest than those at temperate forest in which commonly dominated by several tree species. On the other hand, understorey habitat are covered by canopy forest that determined light intensity penetrating to the ground for bryophytes photosynthesis. More over, the low rate of litter decomposition in the tropical forest may affect the substrates availability for terrestrial bryophytes. The terrestrial substrates in the understorey of primary

forest in the Mount Halimun Salak National Park were restricted, since the ground was mostly covered by leaf litters, herbs and scrub plants. Terrestrial bryophytes were found growing in mats or clusters at patched substrates such as rotten log, humus, or rock at slightly open area in the forest understorey.

The greater richness of the arboreal habitat than the terrestrial habitat has been discussed by numerous authors (Richards 1984; Gradstein & Pocs 1989; Frahm 1990; Frahm & Gradstein 1991; Gradstein *et al.* 2001; Gradstein & Culmsee 2010). Richards (1984) mentioned that bryophytes may be absent on undisturbed soil in lowland rain forests and only locally common in montane forests. Gradstein & Culmsee (2010) also reported that for the arboreal species: liverworts species richness increased toward higher elevation, whereas moss richness decreased.

Bryophytes may represent important components of forest floor and epiphytes communities in the forest ecosystem, contributing high number of species to forest diversity. Vegetation analysis of corridors forest at the Mount Halimun Salak National Park conducted by Sambas and Purwaningsih yield about 27 - 36 species of tree plants in the plot of 0.2 ha (<http://www.tnhalimun.go.id/document.php/document/article/49/38/>). Based on this research it appeared that the richness of bryophytes may exceed that of the tree plant. Based on the species number in the plots, it is estimated that bryophytes may contribute about 46 - 79 species to the plants community in the forest of the Mount Halimun Salak National Park.

Though the difference was not statistically significant (ANOVA,  $n=25$ ,  $p=0.05$ ), species richness in the plot at higher altitude (plot I, 1730 m) tend to be lower than those at the lower altitudes (plot IV, 1000 m). The differences in species richness was also reported by Gradstein and Culmsee (2010) that occurred between lower montane and upper montane rain forest of Lore Lindu National Park in Central Sulawesi. On the other hand, species abundance of bryophytes at higher altitude was higher than those at lower altitudes. The result is in accordance with that of tropical American forest that the coverage of bryophytes increased with the increase of the altitude (Gradstein & Pocs 1989) and also observed between lower montane and upper montane rain forest of Lore Lindu National Park (Gradstein & Culmsee 2010)

Some terrestrial species that have highest coverage in the plots were the mosses species of *Hypnodendron*, *Calicostella papillata*, dan *Trichosteleum boschii*. Those three species were common species, they were often found in the plots (with the frequency of occurrence of about 20 % and they are included in the family Hypnodendraceae, Hookeriaceae, and Sematophyllaceae, respectively. The most dominant arboreal species in terms of coverage are *Syrrhopodon tristichus*, *Syrrhopodon muelleri*, *Mitthyridium junquilianum* (Calymperaceae), *Spruceanthus polymorphus*, *Lejeunea anisophylla* (Lejeuneaceae), *Plagiobhila frondescens*, *Plagiobhila sciophylla*, and *Plagiobhila frondescens* (Plagiobhilaaceae). The moss species of *Syrrhopodon tristichus* and the liverwort species of *Lejeunea anisophylla* were also the most common species which occurred in 40 % of the 25 quadrat samples. This result is relevant to the bryophytes commonly found in oligophotic habitat such as the understorey forest consisting of many dendroid, feather or bracket-type of mosses and liverworts which are specific of this type habitats. These bryophytes belong to the family of Hookeriaceae, Pterobryaceae, Neckeraceae, Plagiobhilaaceae, and Lejeuneaceae (Gradstein & Pocs 1989).

## CONCLUSIONS

Bryophytes communities at primary forest of the Mount Halimun Salak National Park comprised about 150 species of liverworts and mosses found across various terrestrial and arboreal substrates. The species diversity of arboreal bryophytes at 900-1730 m is higher than those of terrestrial bryophytes. Forest at the higher elevation tends to have lower species richness than that at lower elevation. In the contrary, the bryophytes abundances are higher at high elevation compared to that at lower elevation.

## ACKNOWLEDGMENTS

We would like to thank Prof. S. Robbert Gradstein (Museum National D'histoire Naturelle, Department Systematique et Evolution) for the valuable suggestions and review of this manuscript. Indah Wahyuni, Dian Apriani, Marinda Sari Sofiyana, and Saiful Bachri assisted us with collecting samples in the field. Funding for this study was provided by research project of DIPA-BIOTROP DIKTI 2009.

## REFERENCES

- Acebey C, Gradstein SR, Kromer T. 2003. Species richness and habitat diversification of bryophytes in submontane rain forest and fallows in Bolivia. *Journal of Tropical Ecology*, 18: 1-16.
- Andrew NR, Rodgerson L, Dunlop M. 2003. Variation in invertebrate - bryophyte community structure at different spatial scales along altitudinal gradients. *Journal of Biogeography*, 30: 731-746.
- Ariyanti NS, Bos MM, Kartawinata K, Tjitrosoedirdjo SS, Guhardja E, Gradstein SR. 2008. Bryophytes on tree trunks in natural forests, selectively logged forests and cacao agroforests in Central Sulawesi, Indonesia. *Biological Conservation*, 141: 2516-2527.
- Ariyanti NS, Gradstein SR, Sporn SG, Angelika E, Tan BC. 2009. Catalogue of the bryophytes of Sulawesi, Supplement 1. *Blumea*, 54: 287-289.
- Ariyanti NS, Gradstein SR. 2007. Wallace's line and the distribution of the liverworts of Sulawesi. *Cryptog. Bryol.* 28: 3-14.
- Bartram EB. 1939. *The Philippine Journal of Science*. Vol. 68. Manila: Bureau of Printing.
- Botting RS, Campbell J, Fredeen AL. 2008. Contrasting arboreal and terrestrial macrolichen and bryophyte communities in old-growth sub-boreal spruce forests of central British Columbia. *The Bryologist*, 111(4): 607-619.
- Eddy A. 1988. *A Handbook of Malesian Mosses*. Vol. 1, Sphagnales to Dicranales. London: British Museum.
- Eddy A. 1990. *A Handbook of Malesian Mosses*. Vol. 2, Leucobryaceae to Buxbaumiaceae. London: The Natural History Museum.
- Eddy A. 1996. *A Handbook of Malesian Mosses*. Vol. 3, Splachnobryaceae to Leptostomataceae. London: The Natural History Museum.
- Frahm JP, Gradstein SR. 1991. An altitudinal zonation of tropical rain forest using bryophytes. *Journal of Bryogeography*. 18: 75-78.
- Frahm JP. 1990. The ecology of epiphytic bryophytes of Mt. Kinabalu, Sabah (Malaysia). *Nova Hedwigia*, 51: 121-132.

- Gignac LD. 2001. Bryophytes as indicators of climate change. *The Bryologist*, 104: 410 - 420.
- Gradstein SR, Churchill SP, Salazar AN 2001. Guide to the bryophytes of tropical America. New York: Memoirs of the New York Botanical Garden, 86: 1-577.
- Gradstein SR, Culmsee H. 2010. Bryophytes diversity on tree trunks in montane forests of Central Java. *Tropical Bryology*, 31:95-105.
- Gradstein SR, Pocs T. 1989. Bryophytes. *In*: Lieth H, Werger MJA (eds). Tropical rain forest ecosystems. Amsterdam: Elsevier Science Publishers B.V., p. 311-325.
- Gradstein SR, Tan B, King C, Zhu RL, Drubert C, Pitopang R. 2005. A Catalogue of the Bryophytes of Sulawesi, Indonesia. *Journal of the Hattori Botanical Laboratory*, 98: 213-257.
- Gradstein SR. 2011. Guide to the Liverworts and Hornworts of Java. Bogor: SEAMEO BIOTROP.
- Harris ESJ. 2008. Ethnobotany: traditional uses and folk classification of bryophytes. *The Bryologist*, 111 (2): 169-217.
- Hasan M, Ariyanti NS. 2004. Mengenal Bryophyta (Lumut) di Taman Nasional Gede Pangrango. Cibodas: Balai Taman Nasional Gunung Gede Pangrango.
- Longton RE. 1984. The role of bryophytes in terrestrial ecosystems. *Journal of the Hattori Botanical Laboratory*, 55: 147-163.
- McGee GG, Kimmerer RW. 2002. Forest age and management effect on epiphytic bryophyte communities in Adirondack northern hardwood forest, New York, USA. *Canadian Journal of Forest Research*, 32: 1562-1576.
- Menzel M. 1988. Annotated Catalogue of the Hepaticae and Anthocerotae of Borneo. *Journal of the Hattori Botanical Laboratory*, 65: 145-206.
- Nöske N, Hilt N, Werner F, Brehm G, Fiedler K, Sipman HJ, Gradstein SR. 2008. Disturbance effects on diversity in montane forest of Ecuador: sessile epiphytes vs. mobile moths. *Basic and Applied Ecology*.
- Pócs T. 1980. The epiphytic biomass and its effect on the water balance of two rain forest types in the Uluguru Mountains (Tanzania, East Africa). *Acta Botanica Academiae Scientiarum Hungaricae*, 26:143-167.
- Richards PW. 1984. The Ecology of Tropical Forest Bryophytes. *In*: Schuster RM. (ed.) *New Manual of Bryology*, Nichinan: Hattori Botanical Laboratory, p. 1233-1270.
- Sillet TS. 1994. Foraging ecology of epiphyte-searching insectivorous birds in Costa Rica. *Condor*, 96: 863-877.
- Sillett S, Gradstein SR, Griffin D. 1995. Bryophyte diversity of *Ficus* tree crowns from cloud forest and pasture in Costa Rica. *The Bryologist*, 98: 251-260.
- Söderström L, Gradstein SR, Hagborg A. 2010. A checklist of the hornworts and liverworts of Java. *Phytotaxa*, 9: 53-149.
- Sporn SG, Bos MM, Keßler M, Gradstein SR. 2009. Vertical distribution of epiphytic bryophytes in an Indonesian rainforest. *Biodiversity and Conservation*, 19: 745-760.
- Suleiman M, Akiyama M, Tan BC. 2006. A revised catalogue of Mosses reported from Borneo. *Journal of the Hattori Botanical Laboratory*, 99:107-183.
- Tan BC *et al.* 2006. Mosses of Gunung Halimun National Park, West Java, Indonesia. *Reindwartia*, (12): 205-214.
- Tan BC, Engel JJ. 1986. An annotated checklist of Philippine Hepaticae. *Journal of the Hattori Botanical Laboratory*, 60: 283-355.
- Tan BC, Iwatsuki Z. 1991. A new Annotated Philippine Moss Checklist. *Harvard Papers Botany*, 3:1-64.
- Turetsky MR. 2003. The Role of Bryophytes in Carbon and Nitrogen Cycling. *The Bryologist*, 106(3):395-409.

Appendix 1. Alphabetical list of arboreal and terrestrial bryophyte species collected in the plots. a = arboreal; t = terrestrial; + = present; - = absent.

Species	Habitat	Plot I	Plot II	Plot III	Plot IV
<b>Mosses:</b>					
<i>Acanthorrhynchium papillatum</i>	a, t	-	-	+	-
<i>Acroporium diminutum</i>	a, t	+	-	+	+
<i>Acroporium bamulatum</i>	t	+	-	-	-
<i>Acroporium lamprophyllum</i>	a, t	+	+	+	+
<i>Acroporium rufum</i>	a, t	+	-	+	+
<i>Acroporium secundum</i>	a	+	-	-	-
<i>Acroporium sigmatodontium</i>	a, t	+	-	-	+
<i>Calyscostella papillata</i>	t	-	+	-	+
<i>Chaetomitrium lanceolatum</i>	t	-	-	-	+
<i>Dicranoloma blumii</i>	t	-	+	-	-
<i>Dicranoloma braunii</i>	a, t	+	-	-	+
<i>Dicranoloma brevisetum</i>	a, t	+	+	-	+
<i>Distichophyllum schmidii</i>	t	-	+	-	-
<i>Distichophyllum</i> sp. 1	t	+	-	-	+
<i>Ectropobecium</i> sp. 1	t	+	-	+	-
<i>Exostratum blumei</i>	a, t	-	+	-	+
<i>Fissidens crassinervis</i> var. <i>laxus</i>	t	-	-	-	+
<i>Fissidens gedebensis</i>	a	-	+	-	-
<i>Fissidens hollianus</i>	a, t	-	+	-	-
<i>Floribundaria floribunda</i>	a, t	-	+	-	-
<i>Himantocladium plumula</i>	a	-	-	-	+
<i>Homaliodendron flabellatum</i>	a	-	+	-	-
<i>Homaliodendron javanicum</i>	a	-	-	-	+
<i>Hypnaceae</i> sp. 1	t	-	+	-	-
<i>Hypnodendron</i> sp. 1	t	+	-	-	-
<i>Isopterygium albescens</i>	a, t	+	-	+	+
<i>Isopterygium bancanum</i>	a, t	-	-	-	+
<i>Isopterygium minus tirameum</i>	a, t	+	-	-	+
<i>Leucobryum bowringii</i>	a	-	-	-	+
<i>Leucobryum candidum</i>	t	-	-	-	+
<i>Leucobryum javense</i>	a, t	+	+	+	+
<i>Leucobryum juniperoideum</i>	a	-	-	+	-
<i>Leucophanes massartii</i>	a, t	-	+	+	+
<i>Leucophanes octoblepharoides</i>	a, t	-	+	+	+
<i>Lopidium</i> sp. 1	a	-	-	-	+
<i>Lopidium struthiopteris</i>	a	-	+	-	-
<i>Lopidium trichocladon</i>	a	-	+	-	-
<i>Mitthyridium flavum</i>	a	-	-	+	-
<i>Mitthyridium junquilianum</i>	a, t	-	-	+	-
<i>Mitthyridium wallisii</i>	a, t	-	-	+	-
<i>Neckera tjibodensis</i>	a	-	-	-	+
<i>Pelekium velatum</i>	a, t	-	+	-	-
<i>Pinnatella anacampitolepis</i>	a	-	+	-	-
<i>Pinnatella</i> cf. <i>ambigua</i>	a	-	-	-	+
<i>Pinnatella microptera</i>	a	-	+	-	-
<i>Pinnatella</i> sp. 1	a	-	+	-	-
<i>Pogonatum macrophyllum</i>	t	+	-	-	-
<i>Pterobryopsis gedebensis</i>	a	-	-	-	+
<i>Pyrrobryum medium</i>	a	-	+	-	-
<i>Pyrrobryum spiniforme</i>	a	+	+	-	+

## Appendix 1. Continued

Species	Habitat	Plot I	Plot II	Plot III	Plot IV
<i>Symphysa dontella attenuatula</i>	a	-	-	-	+
<i>Symphysodontella cylindrica</i>	a	-	-	-	+
<i>Syrrhopodon alboraginus</i>	a	-	-	+	-
<i>Syrrhopodon muelleri</i>	a	-	-	+	+
<i>Syrrhopodon prolifer</i>	a	-	-	+	-
<i>Syrrhopodon tristichus</i>	a, t	+	-	+	-
<i>Taxitbelium instratum</i>	a	-	-	-	+
<i>Taxitbelium is ocladum</i>	t	+	-	-	-
<i>Trichosteleum boscbii</i>	t	-	-	+	+
<i>Trichosteleum elegantissimum</i>	a, t	+	-	+	-
<i>Trimegistia calderensis</i>	a	+	-	-	-
<b>Liverworts:</b>					
<i>Aeromastigum divaricatum</i>	a	+	-	+	-
<i>Aneura pinguis</i>	t	-	+	-	-
<i>Archielejeunea planiuscula</i>	a	-	-	-	+
<i>Bazzania intermedia</i>	a	+	+	-	+
<i>Bazzania</i> sp. 1	a	-	-	-	+
<i>Bazzania</i> sp. 2	a	-	-	+	-
<i>Bazzania</i> sp. 3	a	-	-	-	+
<i>Bazzania</i> sp. 4	a	+	-	-	-
<i>Bazzania tridens</i>	a	+	-	+	+
<i>Bazzania vittata</i>	a, t	+	+	+	-
<i>Bazzania wallisiana</i>	a	+	-	-	-
<i>Calypogaea goebelii</i>	a	+	-	-	-
<i>Ceratolej eunea belangeriana</i>	a	-	-	-	+
<i>Cheilolejeunea ceylanica</i>	a, t	-	-	+	+
<i>Cheilolejeunea imbricata</i>	a	-	-	+	+
<i>Cheilolejeunea longiloba</i>	a	+	-	-	+
<i>Chiloscyphus minor</i>	a	-	-	-	+
<i>Chiloscyphus muricatus</i>	a	-	-	-	+
<i>Cololejeunea</i> sp. 1	t	-	-	+	-
<i>Drepanolejeunea angus ifolia</i>	a	+	-	-	-
<i>Drepanolejeunea ternatensis</i>	a	+	-	+	-
<i>Frullania apiculata</i>	a	-	-	+	+
<i>Harpalejeunea filicuspis</i>	a	-	-	+	-
<i>Harpalejeunea filicuspis</i>	t	-	-	+	-
<i>Herbertus dricanus</i>	a	+	-	-	-
<i>Heteroscyphus argutus</i>	a, t	-	+	+	+
<i>Heteroscyphus coalitus</i>	t	-	+	-	-
<i>Heteroscyphus succulentibus</i>	a, t	-	+	-	+
<i>Heteroscyphus zollingeri</i>	t	+	-	-	+
<i>Jubula</i> sp. 1	t	+	-	-	-
<i>Kurzia gonyotricha</i>	a	+	-	-	-
<i>Lejeunea anisophylla</i>	a, t	+	+	+	+
<i>Lejeunea discreta</i>	a	+	-	+	+
<i>Lejeunea eifigii</i>	a	-	+	-	-
<i>Lejeunea exilis</i>	a	-	-	-	+
<i>Lejeunea obscura</i>	a, t	-	+	+	+
<i>Lejeunea punctiformis</i>	a	-	-	-	+
<i>Lejeunea sordida</i>	a	-	-	+	+
<i>Lejeunea</i> sp. 1	a	-	+	+	-
<i>Lepidolejeunea bidentula</i>	a	-	-	+	-

## Appendix 1. Continued

Species	Habitat	Plot I	Plot II	Plot III	Plot IV
<i>Lepidolejeunea integristipula</i>	a	-	-	-	+
<i>Lepidozia hasskarliana</i>	a	+	-	-	-
<i>Lepidozia trichodes</i>	a	-	+	-	-
<i>Lepidozia wallichiana</i>	a, t	+	-	+	-
<i>Leujenea anisophylla</i>	a	-	+	-	-
<i>Lophocolea bidentata</i>	a, t	-	-	+	+
<i>Lophocolea minor</i>	t	-	+	-	-
<i>Lopholejeunea eulophia</i>	a	-	-	-	+
<i>Lopholejeunea horticola</i>	a	-	-	-	+
<i>Lopholejeunea nigricans</i>	a	-	-	-	+
<i>Lopholejeunea subfusca</i>	a	-	-	-	+
<i>Lopholejeunea zollingeri</i>	a	+	-	-	+
<i>Mastigolejeunea auriculata</i>	a	-	+	-	-
<i>Metalejeunea cuculata</i>	a	-	-	-	+
<i>Metzgeria leptoneura</i>	a	+	-	-	-
<i>Metzgeria</i> sp. 1	a	-	-	-	+
<i>Plagiochila bantamensis</i>	a	-	+	-	+
<i>Plagiochila dendroides</i>	a	+	+	-	-
<i>Plagiochila frondescens</i>	a	+	+	-	+
<i>Plagiochila javanica</i>	a	-	+	-	+
<i>Plagiochila jungbumbiana</i>	a, t	-	+	+	+
<i>Plagiochila obtusa</i>	a	-	-	-	+
<i>Plagiochila parvifolia</i>	t	-	-	-	+
<i>Plagiochila pleurata</i>	a	-	-	+	-
<i>Plagiochila propingua</i>	a	+	-	-	+
<i>Plagiochila sciophylla</i>	a, t	+	+	-	+
<i>Plagiochilium oppositum</i>	a	+	-	-	+
<i>Ptilanthus striatus</i>	a	-	+	-	-
<i>Radula javanica</i>	a	+	-	+	+
<i>Radula multiflora</i>	a	-	+	-	+
<i>Radula retroflexa</i>	a	-	+	+	+
<i>Riccardia</i> sp. 1	t	-	+	-	-
<i>Schistochila aligera</i>	a	-	-	-	+
<i>Schistochila doriae</i>	a	-	+	-	-
<i>Schistochila sciurea</i>	a	+	-	-	-
<i>Spruceanthus polymorphus</i>	a	-	+	-	-
<i>Telenarea neesii</i>	a, t	+	+	-	+
<i>Thysananthus retusus</i>	a	-	-	-	+
<i>Thysananthus spatulistipus</i>	a	-	-	+	+
<i>Trichocolea tomentella</i>	a, t	+	-	-	+
<i>Zoopsis lukienensis</i>	t	+	-	-	-