Mosses diversity from Lombok island, West Nusa Tenggara

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Abstract. Lombok is a part of the Lesser Sunda Islands located in the West Nusa Tenggara Province. The diversity of mosses reported by Touw in 1992. The mosses research at surrounding Rinjani National Park was be conducted. The result reported 72 species of mosses including 46 genera and 21 families. The higher of mosses diversity is Meteoriaceae. More than 27% of mosses at the site is suggested as new records from Lombok.

1. Introduction
Lombok is one island of the Lesser Sunda Islands located in West Nusa Tenggara province. This island has some conservation areas and one of them is Rinjani Mount National Park. This conservation area located at 116°21'30" - 116°34'15" E and 8°18'18" - 8°32’19" S. The topography is mountainous with varying land slopes: flat, bumpy, hilly to mountainous, with an area of 40,000 Ha and altitude 500 - 3726 m asl (top of Rinjani Mount). The annual rainfall up to 2000 ml. Three types of ecosystem in this national park were tropicallowland rain forest, sub mountain tropical rain forest and sub alpine vegetation. Rinjani Mount National Park is a beautiful forest and as sources of germplasm, research, education and tourism[1].

Plant diversity researches on this island have been carried out including mosses group. Some researchers have conducted moss inventories on this island such as Elbertin 1909, Balasz in 1965 and Touw & Snoek in 1986. The total collections are 150 species [22]. The interesting of the occurrence of long-time gaps has not been rediscovered of mosses in this island (around 29 years) then it need to re-collect on old site and new sites to increase of mosses diversity in this island.

2. Materials and Methods

2.1. Research areas
The inventory was carried out in some places surrounding Rinjani National Park at April to May 2015. The areas were Kembang Kuning Resort Forest, Jeruk manis, Sikur, East Lombok; Aikmal Resort Forest, East Lombok; Forest in surrounding hot spring water at Sebau, East Lombok and surrounding Pusuk Mount natural reserves forest at West Lombok.

2.2. Method
The field study method has refered to the Rugayah et al. (2004) and Cornard (1982). Identification of all samples were done in the Herbarium Bogoriense. Some references used to identify such as Mosses of the Philippines (Bartram, 1939), A Handbooks of Malesian Mosses volume 1, 2,3 (Eddy, 1988;
Moss and Liverworts of Hongkong volume 1&2 (So, 1995; Zhu & So, 1996) and the herbarium Bogoriense mosses specimen collections. The distribution tracking from all mosses in research areas were done manually or digitally to find out the taxonomic status. All moss collections from research areas are processed as herbarium collections after data collection, labeling and packing, then are stored in the Herbarium Bogoriense.

3. Results and Discussion

The mosses inventory from research areas was collected about 106 specimen samples and were identified as 72 species, 46 genera and 21 families. The highest moss diversity in the research areas is Meteoriaceae (Figure 1) and Meteorium polytrichum Dozy & Molk. is the common species which hanging on twigs in the forest at 800-1550 m asl. The Meteoriaceae is a group of 'pleurocarpus' moss, creeping or hanging on trees in the forest. According to Streiman [22], this family contain 21 genera and 300 species as epiphytes in moist and dense forests at the tropics, subtropics and temperate regions. Meteoriaceae along with Plagiochillaceae, Pterobryaceae, Neckeraceae, Phyllogoniaceae and Lejeuneaceae which known as scio-hygrophilous mosses were found the lowest branches of trees [19]. In this research, members of this family were found hanging on the lowest branches of pine trees in the humid forest at 1146 m asl. The environmental condition of this forest is suitable environment for growth and development of the Meteroriaceae so that its presence in the forest is abundant.

![Figure 1. Mosses diversity from research areas based on family group.](image-url)

Mosses diversity from Lombok island were recorded about 150 species by Touw (1992) based on specimen collections from Elber in 1909, Balasz in 1965, Touw & Snoek in 1986. Herbarium Bogoriense is deposited 21 species of mosses from Lombok Island. While the research in 2015 collected about 72 species of mosses from surrounding Rinjani Mount National Park. The compiling of all moss data collections from Lombok Island reported 208 species (Figure 2).

Mosses in Gunung Rinjani National Park has high species diversity because this region has many ecosystem types from lowland tropical rainforests to mountain tropical forests and has relatively undisturbed primary forests that are suitable as habitat for growth and development of moss. Gradstein (2001) reports that the diversity of bryophyte in the tropical forests of sub-mountains and mountains is higher compared to lowland tropical forests.
Based on the Venn diagram (Figure 1), two species of moss (*Aerobryopsis wallichii* and *Pyrrhobryum spiniforme*) were rediscovered at the research areas. *Aerobryopsis wallichii* has a synonym *Aerobryopsis longissima*. It was collected by J. Elber in 1909 (E 1123, 2127B, 2188, 2193 mix) from Rinjani Mount (2400-2650 m asl) and Kembang kerang (1350-2200 m asl). Touw & Snoek also collected it in 1986 (TS 22224) from Tetenbatu (700-800 m asl). This research rediscovered it was hanging on twigs in the forest surrounding Jeruk Manis waterfall in Kembang Kuning Resort, Sikur, East Lombok (FIW 4169) and in Pusuk Protected Forest, Sebau, West Lombok (FIW 4289). While *Pyrrhobryum spiniforme* was collected from Pusuk Mount by by J. Elbert in 1909 (600-900 m asl; E. 1852 & 1921) and from Rinjani Mount (1000-2050 m asl) by J.Elbert (E. 2192), Balasz in 1965 (Balasz 47E) and Touw & Snoek in 1986 (TS22359). The rediscovery of both mosses in research areas with a long-time gap (Elbert- Balasz: 56 years; Balasz – Touw &Snoek: 21 years; Touw & Snoek – FIW: 29 years) indicated that the environmental condition in this national park areas are well preserved.

Based on the diagram above (Figure 1), it showed that 57 species (11 species mosses were unpublished and deposited in Herbarium Bogoriense and 46 species from research areas) were proposed as new records for Lombok Island. The appearance of new records from the research areas can be caused by nature and anthropogenic activities. The environment changing is caused by natural disasters such as landslides, the fall of old trees in the forest, the activities of Rinjani Mount (nine times of eruption during 1874-2004) and forest change of the other mount surrounding Rinjani Mount National Park [1]. While anthropogenic changing is caused by the addition of tourism facilities in the Gunung Rinjani National Park area. The nature and anthropogenic changing will have an impact on the changing microclimate. Sonnleitner, et al. (2009) reported that the microclimatic parameters (availability of temperature, relative humidity and light) and phorophyte identities were correlated to the differences of cover, diversity and species composition of bryophyte. Microclimate is also regarded as the major driver of epiphyll distribution [5, 13, 14, 17, 25]. The small environmental changing will
greatly affect on the mosses and other microorganism in its habitat. The addition of moss diversity in these environments can occur due to the moss spores which are small and easily dispersed by the wind. If the spores find a suitable environment, it will germinate and grow into mature moss plants. Likewise, the development of tourism in the national park area such as the addition of tourism supporting facilities will also slightly change the condition of the previous forest.

Table 1. New records of mosses for Lombok island.

| Family / Species Name | Field | Bo Coll. | Loc. Coll. | Date |
|------------------------|-------|----------|-----------|------|
| **BARTRAMIACEAE:**     |       |          |           |      |
| 1. Philonotis fontana (Hedw.) Brid. |       |          |           |      |
| **BRACHYTHECIACEAE:**  |       |          |           |      |
| 2. Eurhynchium striatum (Schreb. ex Hedw.) Schimp. |       |          |           |      |
| **BRYACEAE:**          |       |          |           |      |
| 3. Leptostomum erectum R. Br. |       |          |           |      |
| 4. Ptychostomum capillare (Hedw.) D. T. Holyoak. & N. Pedersen |       |          |           |      |
| 5. Trematodon longicollis Michx. |       |          |           |      |
| **CALYMPERACEAE:**     |       |          |           |      |
| 6. Arthrocormus schimperi (Dozy and Molk) Dozy and Molk |       |          |           |      |
| 7. Calymperes afzelii Sw. |       |          |           |      |
| 9. Calymperes boulayi Besch. |       |          |           |      |
| 10. Calymperes palisotii Schwägr. |       |          |           |      |
| 11. Leucophanes angustifolium Renauld & Cardot |       |          |           |      |
| 12. Syrrhopodon proliffer Schwagr. |       |          |           |      |
| 13. Syrrhopodon spiculosus Hook. & Grev. |       |          |           |      |
| **DICRANACEAE:**       |       |          |           |      |
| 14. Campylopus schmidii (Müll. Hal.) A. Jaeger |       |          |           |      |
| 15. Campylopus introflexus (Hedw.) Brid. |       |          |           |      |
| 16. Dicranoloma assimile (Hampe.) Paris |       |          |           |      |
| 17. Dicranoloma billardieri (Brid.) Paris |       |          |           |      |
| 18. Leucobryum juniperoides (Brid.) Mull. Hall |       |          |           |      |
| 19. Leucoloma molle (Müll. Hal.) Mitt. |       |          |           |      |
| 20. Microcampylopus khasianus (Griffiths) Giese & J.-P. Frahm |       |          |           |      |
| 21. Pilopogon blumii Broth |       |          |           |      |
| **FISSIDENTACEAE:**    |       |          |           |      |
| 22. Fissidens anomalus Mont. |       |          |           |      |
| 23. Fissidens braunii (Müll. Hal.) Dozy & Molk. |       |          |           |      |
| 24. Fissidens laxus Sull. & Lesq. |       |          |           |      |
| 25. Fissidens delicatus (Reinw. & Hornsch.) A. Jaeger |       |          |           |      |

Note: 1= Tetebatu, East Lombok; 2: Kembang Kuning Resort, Jeruk Manis, Sikur, East Lombok; 3: Aikmal Resort, East Lombok; 4: Alor Gedang, East Lombok; 5: Sebau, West Lombok; 6: Pusuk Mount., West Lombok; 7: Joben, Rinjani National Park, Lombok; 8: Rinjani Mount.
### Table 1 (Continue)

| Family / Species Name: | Field | Bo Coll. | Loc. Coll. | Date  |
|------------------------|-------|----------|------------|-------|
| **FUNARIACEAE:**       |       |          |            |       |
| 26. Funaria hygrometrica var. clavescens (Schwaegr.) Mont. | √     | 8        | 1909       |       |
| **GRIMMIIACEAE:**      |       |          |            |       |
| 27. Rhacomitrium hypnoïdes Lindb. | √     | 8        | 1909       |       |
| **HYPNACEAE:**         |       |          |            |       |
| 28. Ectropothecium dealbatum (Reinw. & Hornsch.) A. Jaeger | √     | 1        | 2015       |       |
| 29. Ectropothecium ichnotocladum (Mull. Hal.) A. Jaeger | √     | 2        | 2015       |       |
| 30. Ectropothecium falciforme Jaeg. | √     | 8        | 1909       |       |
| 31. Isopterygium minutirameum (Müll. Hal.) A. Jaeger | √     | 2        | 2015       |       |
| 32. Vesicularia montagnei (Schimp.) Broth. | √     | 2        | 2015       |       |
| **METEORIACEAE:**      |       |          |            |       |
| 33. Aerobryopsis subleptostigmata Broth. & Paris | √     | 1        | 2015       |       |
| 34. Barbella flagellifera (Cardot) Nog. | √     | 5        | 2015       |       |
| 35. Barbella rufifolioides (Broth.) Broth. | √     | 2        | 2015       |       |
| 36. Floribundaria pseudofloribunda M. Fleisch. | √     | 5&2      | 2015       |       |
| 37. Meteorium subpolytrichum (Besch.) Broth. | √     | 2        | 2015       |       |
| **NECKERACEAE:**       |       |          |            |       |
| 38. Neckera complanata (Hedw.) Huebener | √     | 1        | 2015       |       |
| 39. Pinatella ambiguа (Bosch & Sande Lac.) M. Fleisch. | √     | 2        | 2015       |       |
| **ORTHOTRICHACEAE:**   |       |          |            |       |
| 40. Macromitrium falcatulum Müll. Hal. | √     | 2        | 2015       |       |
| 41. Macromitrium fasciculare Mitt. | √     | 1        | 2015       |       |
| 42. Macromitrium goniorrhynchum Mitt. | √     | √        | 8          | 1909  |
| 43. Macromitrium orthostichum Nees ex Schwägr. | √     | 3        | 2015       |       |
| 44. Macromitrium schimidi Mull. Hal. | √     | 2        | 2015       |       |
| 45. Orthotrichum schoddei Lewinsky | √     | 3        | 2015       |       |
| **POTTIACEAE:**        |       |          |            |       |
| 46. Barbula laxiretis Broth. | √     | 8        | 1909       |       |
| 47. Barbula unguiculata Hedw. | √     | 6        | 2015       |       |
| 48. Hymenostylium luzonense Broth. var minus Broth | √     | 8        | 1909       |       |
| **PTEROBRYACEAE:**     |       |          |            |       |
| 49. Calyptotheicum phyllogonioides Nog. & X.J. Li | √     | 3&6      | 2015       |       |
| **SEMATOPHYLLACEAE:**  |       |          |            |       |
| 50. Acroporioum fuscoflavum (Paris) Broth. | √     | 2        | 2015       |       |
| **THUIDIACEAE:**       |       |          |            |       |
| 51. Herpetineuron toccoae (Sull. & Lesq.) Cardot | √     | 2        | 2015       |       |
| 52. Thuidium assimile (Mitt.) A. Jaeger | √     | 2        | 2015       |       |
| 53. Thuidium delicatulum (Hedw.) Schimp. | √     | 5        | 2015       |       |
| 54. Thuidium investe (Mitt.) A. Jaeger | √     | 2        | 2015       |       |
| 55. Thuidium meyenianum (Hampe) Dozy & Molk. | √     | 1        | 2015       |       |

Note: 1= Tetebatu, East Lombok; 2: Kembang Kuning Resort, Jeruk Manis, Sikur, East Lombok; 3: Aikmal Resort, East Lombok; 4: Alor Gedang, East Lombok; 5: Sebau, West Lombok; 6: Pusuk Mount., West Lombok; 7: Joben, Rinjani National Park, Lombok; 8: Rinjani Mount.
Mosses are a simplest group of chlorophyllous plants which grow as epiphyte in a variety of substrates. Mosses in these research areas were found growing on various substrate such as soil, rocks, dead log, decaying wood, and tree trunks. Based on observation data at these research areas, the tree trunk is the best substrate for moss 49.5 % (Figure 3).

Figure 3. Percentage of mosses or

The tree trunks with over grown of moss are Smith (1982) and Bates (2008) reports. Phorophyte and establishment of epiphyllous communities [5 generally have rough skin surfaces or cracks along place to descend of mosses spore and rainwater conditions are suitable and did not find inhibiting f i 24]. Bark structure and microclimate were identific within the forest. Due to the lack of a protective cu conditions [9, 11, 27]. The part of stem that overg because moss requires light for the photosynthesis moderate light levels [12] such as the small gap in f... 

4. Conclusion
Mosses in Gunung Rinjani National Park has high species diversity with 210 species. The long-time gap not re-collected of the moss diversity in the Gunung Rinjani National Park has an impact on the addition of diversity, 42 species were found in the research areas as new records. Aerobryopsis walichii and Pyrrhobryum spiniforme which were rediscovered at the research areas showed that forest management in the Gunung Rinjani National Park area is well preserved.

5. References
[1] Anonymous. 2010 Balai Taman Nasional Gunung Rinjani http://www.tnrinjani.net/statistik-5-sejarahgunungrinjani.html, accessed September 2018
[2] Bartram E B 1939 Mosses of the Philippines The Philippine journal of science 68 (1) 1-437
[3] Bates J W 2008 Mineral nutrition & substratum ecology In Goffinet B & Shaw A J (eds.) Bryophyte biology 2nd ed. (Cambridge: Cambridge University Press) pp 300-356
[4] Cornard H S 1982 How to know Mosses and Liverworts 2nd ed. Wm C. (Dubuque Iowa: Brown Company Publishers) pp 8-14
[5] Coley P D, Kursar T A and J L Machado 1993 Colonization of tropical rain forest leaves by epiphylls: effect of site and host plant leaf lifetime. Ecology 74 619-623
[6] Eddy A. 1988.A. Handbook of Malesian Mosses Volume 1 Natural History Museum Publications London p 204
[7] Eddy A 1990 A Handbook of Malesian Mosses Volume 2 Natural History Museum
Publications London p 256

[8] Eddy A 1996 A Handbook of Malesian Mosses Volume 3 HMSO Publications Centre p277

[9] Gignac D 2001 Bryophytes as indicators of climate change Bryologist 104 410-420

[10] Gradstein S R, Churchill S P and Salasar-Allen, N 2001 Guide to the bryophyte of tropical America (New York: The New York Botanical Garden Press) p 577

[11] Leo´n-Vargas Y, Engwald S, Proctor MCF (2006) Microclimate, light adaptation and desiccation tolerance of epiphytic bryophytes in two Venezuelan cloud forests J Biogeogr. 33 901-913

[12] Marino P C & Salazar Allen N 1993 Tropical epiphyllous hepatic communities growing on two species of shrub in Barro Colorado Island: the influence of light and microsite Lindbergia 17 91-94

[13] Monge-NáJera J 1989 There relationship of epiphyllous liverworts with leaf characteristics and light in Monte Verde Costa Rica Cryptogamic Bryologie 10 345-352

[14] Olarinmoye S O 1974 Ecology of epiphyllous liverworts: growth in three natural habitats in western Nigeria Journal of Bryology 8 275-289

[15] Pósc T 1982 Tropical forest bryophytes in Smith A J E (ed.) Bryophage ecology (London: Chapman & Hall) pp 59–105

[16] Wanek W and Pórtl K 2005 Phyllosphere nitrogen relations: reciprocal transfer of nitrogen between epiphyllous liverworts and host plants in the understorey of a lowland tropical wet forest in Costa Rica New Phytologist 166 577-588

[17] Richards P W 1984 The ecology of tropical forest bryophytes. in Schuster R M (ed.) New manual of bryology The Hattori Botanical Laboratory Nichinan pp 1233-1270

[18] Rugayah, A Retnowati, F I Windadri dan A Hidayat 2004 Pengumpulan Data Taksonomi. In Rugayah, E.A. Widjaja dan Praptiwi, Pedoman pengumpulan data keanekaragaman flora Pusat Penelitian Biologi Bogor – Indonesia p 5-42

[19] Smith A J E 1982 Bryophage Ecology (London: Chapman & Hall) p 521

[20] So M L 1995 Moss and Liverworts of Hongkong vol.1 Biology Department Hongkong Baptist University Hongkong

[21] Sonnleitner M S, Dullinger W, Wanek and H Zechmeister 2009 Microclimate pattern correlate with the distribution of epiphyllous bryophytes in a tropical lowland rain forest in Costa Rica Journal of Tropical Ecology 25 321-330

[22] Streimann H 2011 Taxonomic Studies on Australian Meteoriaceae (Musci).2: The Genera Aerobypopsis, Barbella, Floribundaria, Meteoropsis, Meteorium and Weymouthia Journal of The Hattori Botanical Laboratory 69 277-312

[23] Touw A 1992 A Survey of The Mosses of The Lesser Sunda Islands (Nusa Tenggara) Indonesia Journal of The Hattori Botanical Laboratory 71 289-366

[24] Windadri F I 2009 Mosses diversity on Pandanus at Ujung Kulon National Park, Banten. Jurnal Natuur Indonesienas 11(2) 89-93

[25] Wu P, Li D K and Gao C H 1987 Light and epiphyllous liverworts in the subtropical evergreen forests of South-Eastern China Symposia Biologica Hungarica 35 27–32

[26] Zhu R L and So M L 1995 Moss and Liverworts of Hongkong vol.2 Biology Department Hongkong Baptist University Hongkong

[27] Zott G and Bader M Y 2009 Epiphytic plants in a changing world: global change effects on vascular and nonvascular epiphytes. In: Lu¨ttge U, Beyschlag W, B¨udel B et al (eds) Progress in Botany Series 70 pp 147-170

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