

**THE MOSS FLORA OF IMBAK CANYON
CONSERVATION AREA, SABAH**

CHUA MUNG SENG



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UNIVERSITI MALAYSIA SABAH

UMS

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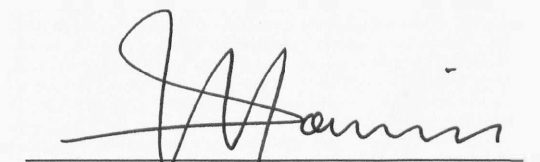
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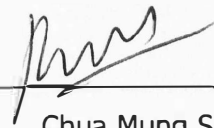


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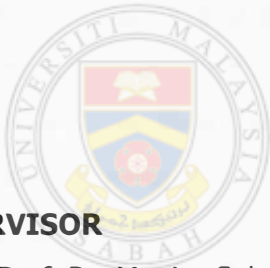
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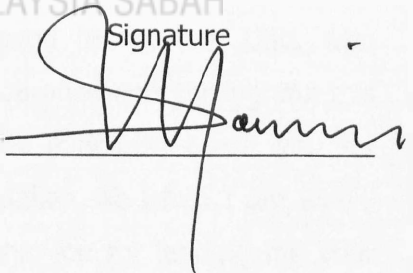


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May all the glory and honour unto our Abba Father. For He is the one who gave me the wisdom, time and strengthened me to finish this study. Without Him, this work is impossible to be accomplished.

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"May you never steal, but steal away my sorrow. May you never lie, but lie with me all night long. May you never cheat, but cheat death."

ABSTRACT

THE MOSS FLORA OF IMBAK CANYON CONSERVATION AREA, SABAH

This study was carried out to collect, identify, prepare descriptions, construct keys to species, and to assess general phytogeographical affinities of mosses from Imbak Canyon Conservation Area (ICCA) within Borneo. A total of 674 moss specimens were collected and examined from the study area. From this collection, 177 species, 13 varieties and four subspecies distributed in 68 genera and 27 families of mosses have been identified. This number represents about 26% of the 741 reported mosses from Borneo and about 32% of the 618 mosses in Sabah. The three largest families are Calymperaceae, Sematophyllaceae and Pylaisiadelphaceae, with 40, 31 and 18 species and varieties, respectively. A total of seven species are added to the moss flora of Borneo: *Ectropothecium striatum*, *Fissidens laxitextus*, *F. pseudoceylonensis*, *F. serratus*, *Taxithelium oblongifolium*, *Clastobryum epiphyllum* and *Macromitrium orthostichum*. Furthermore, four species are new records to Sabah: *Leucobryum sericeum*, *Papillidiopsis complanata*, *Mitthyridium crassum* and *Syrrhopodon scalariformis*. The moss flora of ICCA is similar to that of Maliau Basin Conservation Area in terms of species composition. Interestingly, ICCA has two endemic species to Borneo, *Syrrhopodon scalariformis* and *Chaetomitrium maryatii*, adding value to this conservation area. In conclusion, the moss flora of ICCA is rich and comparable to other large protected areas in Sabah.

ABSTRAK

*Kajian ini dijalankan untuk mengumpul, mengenal pasti, menyediakan diskripsi, membina kekunci kepada spesies, dan menilai afiniti fitogeografi lumut jati dari Kawasan Konservasi Imbak Canyon (ICCA) di Borneo. Sebanyak 674 spesimen lumut jati telah dikumpulkan dan dikaji dari kawasan kajian. Dari koleksi ini, 177 spesies, 13 varieti dan empat subspecies yang terkandung dalam 68 genera dan 27 famili lumut jati telah dikenalpasti. Jumlah ini mewakili kira-kira 26% daripada 741 lumut jati yang telah dilaporkan dari Borneo dan kira-kira 32% daripada 618 lumut jati di Sabah. Tiga Famili terbesar adalah Calymperaceae, Sematophyllaceae dan Pylaisiadelphaceae, masing-masing dengan 40, 31 dan 18 spesies. Sebanyak tujuh spesies adalah tambahan kepada flora lumut jati di Borneo: *Ectropothecium striatulum*, *Fissidens laxitextus*, *F. pseudoceylonensis*, *F. serratus*, *Taxithelium oblongifolium*, *Clastobryum epiphyllum* dan *Macromitrium orthostichum*. Di samping itu, empat spesies adalah rekod baru untuk Sabah: *Leucobryum sericeum*, *Papillidiopss complanata*, *Mitthyridium crassum* dan *Syrrophodon scalariformis*. Flora lumut jati ICCA adalah serupa dengan Kawasan Konservasi Maliau Basin dari segi komposisi spesies. Menariknya, ICCA mempunyai dua species endemik kepada Borneo, *Syrrophodon scalariformis* dan *Chaetomitrium maryatii*, menambah nilai kepada kawasan konservasi ini. Kesimpulannya, flora lumut jati ICCA adalah kaya dan setanding dengan kawasan-kawasan dilindungi yang besar di Sabah.*

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LIST OF ABBREVIATIONS

a.s.l.	above sea level
alt.	altitude
ca.	approximately
BORH	BORNEENSIS Herbarium
cm	centimetre
°C	degree celcius
DO	Dissolve Oxygen
EC	Electron Conductivity
GPS	Global Positioning System
SAN	Herbarium of Sabah Forestry Department, Sandakan
ICCA	Imbak Canyon Conservation Area
MBCA	Maliau Basin Conservation Area
µm	micrometre
mg/L	milligram per litre
mm	millimetre
mS/cm	milliSiemens per centimetre
Mt.	Mountain
o/oo	parts per thousand
pH	power of hydrogen
sp.	species
subsp.	subspecies
TDS	Total Dissolved Solid
var.	variety

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CHAPTER 1

INTRODUCTION

1.1 General

Mosses (Division Bryophyta), together with liverworts (Division Marchantiophyta) and hornworts (Division Anthocerotophyta) comprise the three groups of bryophytes. The term "bryophyte" is originated from Greek language, referring to plants that swell upon hydration. "Bryophytes" is a generic name for plants characterised by a life cycle in which the branched gametophyte is the dominant generation (Vanderpoorten and Goffinet, 2009a), while the sporophyte is unbranched and is permanently attached to the maternal (gametophyte) plant.

Bryophytes are generally small, compact, green plants that are referred as non-vascular plants (Eldridge *et al.*, 2003). They can be seen occupying a wide range of habitats, like soil, rotting wood, dung, and leaves of vascular plants. There are even some bryophytes which hang from branches. Other substrata include very hard surfaces, such as exposed rock and tree barks where most vascular plants hardly grow on (Richards, 1984).

With approximately 13,000 species recognised currently, mosses are the second most diverse phylum of land plants (Goffinet *et al.*, 2008). They are basically separated into two groups, acrocarpous mosses and pleurocarpous mosses. Acrocarpous mosses are erect, tufted, and sparingly branched, whereas most pleurocarpous mosses are prostrate, matted, and highly branched. The former produces sporophytes at the tip of main stems, while latter produces laterally (Malcolm and Malcolm, 2006). Although mosses are small in size, their morphological characters are rather complex.

From the perspective of ecology, even though bryophytes are usually inconspicuous components in the landscape, their occurrence in nearly every terrestrial and aquatic ecosystem on earth reflects their ecological significance

(Hallingbäck and Hodgetts, 2000). Bryophytes display an extremely high water holding capacity that reaches up to about 1,500% of their dry weight (Proctor, 2009). In epiphytic-rich tropical rainforest, epiphytes influence the water budget of a watershed by intercepting considerable quantities of rainfall. Bryophytes also play pivotal ecological roles in terms of nutrient cycles, erosion control and nitrogen budget, as well as a refuge for micro-organisms (Vanderpoorten and Goffinet, 2009b).

At a worldwide scale, as of January 2013, there are only 92 species of bryophytes listed as threatened with extinction in IUCN World Red List (2013). The list is no doubt low as the detailed past and current distribution data of bryophytes are mostly only available in some European countries with a long tradition of floristic mapping (Vanderpoorten and Hallingbäck, 2008). In tropical regions like Borneo, the bryophytes flora is remaining less well known. With the rapid deforestation and degradation of bryophytes habitats at local scale, bryophytes flora needs an urgent assessment.

Imbak Canyon Conservation Area (ICCA), a newly gazetted Class I (Protection) Forest Reserve in the heart of Sabah, is one of the remaining pristine forests in Sabah. This canyon serves as an important catchment area for the Kinabatangan water system, the longest river in Sabah. This conservation area is rich in flora and fauna diversity, and home to many endemics and rare species (Latiff and Sinun, 2011). It is important to carry out comprehensive studies, especially on the inventory of the flora and fauna, in this protected area to be incorporated in its Management Plan. This fundamental information is essential for the authority, which is Yayasan Sabah, for the purpose of biological diversity conservation and sustainable management.

A checklist of mosses from the southern part of ICCA has indicated that this area of lowland and lower montane forests housed a rich bryoflora, especially of lowland entities (Suleiman *et al.*, 2011b). The present study is an effort to fill in the gap of information on the moss flora of ICCA. The results of this work will offer a

basis on bryology for other researchers in other disciplines, such as ecology, phytochemistry and ethnobotany.

1.2 Scope and Objectives

Imbak Canyon Conservation Area currently has two accessible research stations or base camps: Tampoi Research Station and Mount Kuli Research Station. Therefore, this study was carried out in the two stations and their surrounding areas. The main objectives of this study are as follow:

- i. To collect and identify all the species of mosses from ICCA.
- ii. To construct keys to species of the mosses from ICCA.
- iii. To prepare descriptions for all the mosses in ICCA and illustrations of new records.
- iv. To assess the general phytogeographical affinities of ICCA within Borneo.



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CHAPTER 2

LITERATURE REVIEW

2.1 Bryological History in Borneo

The first report of mosses biodiversity in Borneo was done by Dozy and Molkenboer (1844), which recorded 27 species in 16 genera from the collections of Blume, Zippelius, Korthals and De Vriese. Among the renowned authors who had contributed to Bornean bryology were Dixon (1935), Meijer (1954) and Noguchi and Iwatsuki (1972).

Menzel (1988) published the first catalogue of liverworts and hornworts of Borneo, which comprised of 623 taxa in 119 genera and 35 families. After 23 years, Chuah-Petiot (2011) published a checklist of liverworts and hornworts of Malaysia, which reported 764 species and infraspecific taxa in 127 genera and 39 families. She updated the liverworts species in Sabah and Sarawak to 516 taxa and 170 taxa, respectively.

The first comprehensive checklist of Bornean mosses, on the other hand, was completed by Touw in 1978, which reported 607 species and 42 subspecies and varieties, in 164 genera and 41 families. Suleiman *et al.* (2006), after 27 years, revised the checklist to 721 taxa in 185 genera and 50 families. The recent publication by Ellis *et al.* (2010) reported seven new additions of mosses to Borneo, namely *Barbula pachyloma* Broth., *Chionostomum rostratum* (Griff.) Müll. Hal., *Exostratum asperum* (Mitt.) L.T. Ellis, *Mitthyridium papuanum* (Broth.) H. Rob., *Splachnobryum obtusum* (Brid.) Müll. Hal., *Splachnobryum oorschotii* (Sande Lac.) Müll. Hal., and *Trichosteleum mammosum* (Müll. Hal.) A. Jaeger. In the same year, Mohamed *et al.* (2010) added four new records from Maliau Basin Conservation Area, namely *Acroporium ridleyi* Dixon, *Mitthyridium perundulatum* (Broth.) H. Rob., *Schlotheimia emarginato-pilosa* Herzog, and *Wijkia surcularis* (Mitt.) H.A. Crum. Another publication by Ho *et al.* (2010) added *Distichophyllum brevicuspes* M.Fleisch. to the moss flora of Borneo in the same year. The two latest publications

by Suleiman *et al.* (2011a, 2011b) added one new record respectively, namely *Macromitrium salakanum* Müll.Hal. and *Mitthyridium fasciculatum* subsp. *cardotii* (M.Fleisch.) B.C.Tan & L.T.Ellis. With these additions, the current number of moss flora in Borneo is updated to 741 taxa.

2.2 Bryoflora of Sabah

2.2.1 Bryological History

In the year of 1845, the very first bryophytes collection in Sabah was done by a British colonial officer, Hugh Low. The bryophytes collected by Low and Motley from Labuan were later identified by Mitten, Dozy and Molkenboer, and Sande Lacoste, with the materials kept in the herbarium of the New York Botanical Garden and Rijksherbarium Leiden, the Netherlands. Subsequent bryophytes collections in Sabah were carried out by Burbridge from November 1877 to August 1878, Whitehead from January 1887 to February 1888, and Haviland from March to April 1892 (Frahm *et al.*, 1990). The bryophytes collected by these collectors, which consisted of 31 mosses and 14 liverworts, were identified by Mitten and Wright; the materials were deposited in the herbaria of the New York Botanical Garden and the British Museum, London.

During the last century, the lowlands bryophytes of Sabah were studied by Dixon (1916) using the collection of 135 hepatics of Reverend Charles Herbert Binstead which was collected in April/May 1913. The specimens are kept in the British Museum. In 1933, a chaplain of U.S. Army Joseph Clemens and his wife Mary collected about 100 bryophytes from Mount Kinabalu, which were later identified by Bartram and kept in Farlow Herbarium of Cambridge University, USA. Subsequently, a Dutch botanist named Willem Meijer, continued the collecting activities after the Second World War and his collection is kept in Rijksherbarium Leiden (Frahm *et al.*, 1990).

In 1963, the Japanese "Hattori Botanical Laboratory Research Expedition" had set a milestone in exploring the bryophytes of Sabah. Several thousand specimens were collected by Zenoske Iwatsuki and Masami Mizutani and kept in

the herbarium of the Hattori Botanical Laboratory in Nichinan, Japan; the duplicates are kept in the herbarium of the Sabah Forestry Department (SAN) in Sandakan, Sabah (Noguchi and Iwatsuki, 1972). Another Japanese Expedition, "Southeast Asia Science Expedition of Osaka University 1968/1969", also chose Mount Kinabalu as the collecting site and collected 660 mosses and 330 hepatics (Frahm *et al.*, 1990). The collection is kept in the herbarium of Osaka University in Osaka, Japan.

With the tremendous quantity of tropical montane flora and fauna, Mount Kinabalu was suggested as one of the four hot spots for bryophytes by Tan and Iwatsuki (1999). In 1986, an altitudinal transect was carried out at Mount Kinabalu by the members of the BRYOTROP project funded by the German Research Foundation. For the first time not only collections were made but ecological and plant sociological studies were also carried out (Frahm *et al.*, 1990). The herbarium materials are kept in the Botanical Museum in Berlin, with duplicates in SAN.

The BRYOTROP project had contributed greatly to several treatments of families and genera of mosses of Sabah, such as *Dicranoloma* and *Brotherobryum* (Tan, 1989), Leucobryaceae (Enroth, 1989b), Polytrichaceae and Buxbaumiaceae (Hyvönen, 1989a), Fissidentaceae (Tan and Iwatsuki, 1989), Rhizogoniaceae (Touw, 1989a), Hypnodendraceae (Touw, 1989b), Calymperaceae (Menzel and Schultze-Motel, 1990), Sphagnopsida and Andreaeopsida (Menzel and Schultze-Motel, 1991), Meteoriaceae (Menzel, 1992), and the genus *Acroporium* (Sematophyllaceae) (Tan, 1994).

Sabah is continuously being explored by both local and foreign bryologists, with Mount Kinabalu as the centre of attention. For example, Mohamed (1995) reported 106 mosses in 58 genera and 25 families of mosses from Sayap, Kinabalu Park, while Akiyama *et al.* (2001) recorded 203 species in 111 genera and 40 families of bryophytes from the mountain. Mount Kinabalu is still attracting many bryologists and new species are still being described in this century. The latest addition was by Katagiri *et al.* (2012), with a new liverwort species, *Eotrichocolea furukii* T. Katagiri.

Bryophytes diversity in other areas within Sabah was only extensively explored in the last 15 years. For example, Suleiman and Edward (2002) recorded 153 species of mosses in 73 genera and 26 families from Mount Trus Madi, the second highest mountain in Malaysia. Lower Kinabatangan, a lowland rainforest at the eastern part of Sabah was accessed through a scientific expedition where 47 mosses in 24 genera and 12 families were recorded (Suleiman *et al.*, 2003). Crocker Range Park near Ulu Kimanis, in Papar District at the western part of Sabah recorded 126 species of mosses in 74 genera and 27 families (Suleiman and Akiyama, 2004).

2.2.2 Moss Flora of Sabah

Touw (1978) listed 447 taxa of mosses in Sabah based on literature from 1844 to 1978. Suleiman *et al.* (2006) compiled the numerous new additions of mosses to Sabah from 1978 to mid of 2005. A total of 135 taxa of mosses were added to the moss flora of Sabah, totaling to 582 taxa in 185 genera and 50 families.

Andi and Suleiman (2005) published a preliminary checklist of mosses of Meliau Range in Ulu Tongod Forest Reserve Sandakan. They covered from lowland to the highest peak, Mount Meliau (1,433 m). They reported 70 species with five varieties of mosses in 31 genera and 18 families. Among them six species were new to Sabah, namely *Acroporium downii* (Dixon) Broth., *Acroporium strepsiphyllum* (Mont.) B.C.Tan var. *strepsiphyllum*, *Chaetomitrium poecilophyllum* Dixon, *Cladopodanthus heterophyllus* (M.Fleisch.) E.B.Bartram, *Mitthyridium wallisii* (Müll. Hal.) H.Rob., and *Papillidiopsis bruchii* (Dozy & Molk.) W.R.Buck & B.C.Tan.

Mosses from the southern part of Maliau Basin Conservation Area studied by Suleiman and Akiyama (2007) reported 86 taxa in 40 genera and 20 families. The study was carried out at Camel Trophy Camp and Agathis Camp within the elevation of 800-1,100 m a.s.l. They had discovered five new records of mosses for Sabah, namely *Leucobryum bowringii* Mitt., *Syrrhopodon sarawakensis* (Dixon) W.R.Reese, *Trismegistia korthalsii* (Dozy & Molk.) Broth., *Clastobryum cuculligerum* (Sande Lac.) Tixier, and *Syrrhopodon parasiticus* (Sw. ex Brid.) Besch. In addition, they described two new species of mosses from Maliau Basin, namely

Chaetomitrium maryatii H.Akiyama & M.Suleiman and *Trismegistia maliauensis* H.Akiyama & M.Suleiman (Akiyama and Suleiman, 2001).

Maliau Basin was further investigated by Mohamed *et al.* (2010) from north-western part of the basin and a total of 120 taxa in 24 genera and 15 families of mosses were collected. The study was carried out at Eucalyptus camp and adjacent areas within 980 m to 1,200 m a.s.l. Among the collections, eight species were new to Sabah, namely *Aerobryopsis subleptostigmata* Broth. & Paris, *Campylopus serratus* Sande Lac., *Chaetomitrium horridulum* Bosch & Sande Lax., *Distichophyllum spathulatum* (Dozy & Molk.) Dozy & Molk., *Ectropothecium eleganti-pinnatum* (Müll. Hal.) A. Jaeger, *Garovaglia angustifolia* Mitt., *Mitthyridium obtusifolium* (Lindb.) H.Rob., and *Mitthyridium subluteum* (Müll. Hal.) H.K. Nowak.

Meanwhile, Higuchi *et al.* (2008) reported 97 species of mosses in 43 genera and 18 families from a short visit to Mount Kinabalu and Mahua in the Crocker Range. Their study covered the Summit Trail from Timpohon Gate (1,860 m a.s.l.) to Low's Peak (4,095 m a.s.l.), as well as Mahua waterfall (1,000 m a.s.l.). From their collection, they added three species as new records to Sabah, namely *Ditrichum heteromallum* (Hedw.) E. Britton, *Fissidens braunii* (Müll. Hal.) Dozy & Molk., and *Syrrophodon tjibodensis* M.Fleisch.

Lowland areas in Sabah received less attention from bryologists. However, Suleiman *et al.* (2009) recorded 56 taxa of mosses in 31 genera and 14 families from Golden Hope oil palm plantation and surrounding areas. Although this area is a disturbed area, they managed to collect two new records for Sabah, namely *Acroporium convolutum* var. *horridulum* (E.B. Bartram) B.C. Tan, T.J. Kop. & D.H. Norris and *Ectropotheciella distichophylla* (Hampe ex Dozy & Molk.) M. Fleisch.

The latest addition to the moss flora of Sabah was *Distichophyllum santosii* E.B.Bartram and *Mitthyridium constrictum* (Sull.) H. Rob. from Mount Lumaku, Sipitang (Suleiman *et al.*, 2011a). The collections were carried out at the Muaya Research and Education Centre (700-1,200 m a.s.l.) and summit region of Mount Lumaku (1,600-1,900 m a.s.l.).

Currently, the moss flora of Sabah consists of 618 taxa in 186 genera and 50 families, an addition of 36 taxa in 25 genera and 14 families since mid of 2005. The moss flora of Sabah constitutes more than three-fourth of the 741 taxa or ca. 87 % of the mosses reported for Borneo. This is due to the diverse forest that ranged from lowlands to subalpine forests, attracting intensive bryological works as compared to other parts of Borneo (Touw, 1978).

2.3 Imbak Canyon Conservation Area

2.3.1 Background

Imbak Canyon Conservation Area (ICCA) is located near to the heart of Sabah, north of the Maliau Basin Conservation Area, and west of the Danum Valley Conservation Area. It is approximately 90 km south of Telupid and 300 km from the capital of Sabah, Kota Kinabalu.

Formerly, this canyon was part of a timber concession assigned by the state government of Sabah to Yayasan Sabah. However, recognising the importance of biodiversity of this area, it is designated as a conservation area in year 2003 for the purpose of research, education and eco-tourism. Subsequently, in year 2009, this conservation area was gazetted as Class I Forest Reserve. With a total area of ca. 30,000 ha, ICCA encompasses a canyon and two ridge-top Virgin Jungle Reserves, which consists of pristine lowland rainforest dominated by dipterocarp trees (Anon., 2011).

To date, there were three major scientific expeditions organised by various agencies to explore the conservation area. The first expedition was initiated by the Sabah Forestry Department in year 2000 and the main focus was at the entrance of the canyon, currently known as Tampoi Research Station. The second expedition in year 2004 took place in the heart of the canyon. It was participated by both local and foreign institutions and organisations, including Sabah Forestry Department Research Centre, The Royal Society, Royal Botanical Gardens, Kew, Kyoto University, Tokyo University, Japanese International Corporation Agency, Universiti Malaysia Sabah, WWF Malaysia, and SOS Rhino (Anon., 2011).