An updated account on the bryophyte diversity of Batu Caves, Selangor, Malaysia, with two new records for Peninsular Malaysia

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Abstract : Recent surveys to various locations within the Batu Caves complex recorded 56 species of bryophytes. Of these, 16 (in nine genera and four families) belong to liverworts (Marchantiophyta) and 40 (in 29 genera and 16 families) are mosses (Bryophyta). Among the liverworts, members of Lejeuneaceae are best represented with a total of 13 species. Fissidentaceae is the most diverse moss family with six species encountered. Two new liverwort records, *Cololejeunea pseudostipulata* (Schiffn.) Benedix and *C. raduliloba* Steph., are reported for the first time for Peninsular Malaysia. An extremely rare moss species, *Erpodium biseriatum* (Austin) Austin, formerly documented but without a reference sample for Peninsular Malaysia, was collected on two survey trips. Batu Caves is also the second locality for another two rare mosses in Peninsular Malaysia. Of the earlier Batu Caves literature and collections, this study added further species to the overall moss diversity of Batu Caves, bringing the total to 54 species. It is uncertain whether recent human activities including fire have had a significant impact on bryophyte diversity. Further investigation through continuous field collection to better understand the succession of bryophytes is needed, also to aid conservation efforts aim to safeguard rare bryophyte species on Malaysian karst hills.

Keywords: Kuala Lumpur, liverwort, moss, plant conservation, tower karst

INTRODUCTION

Batu Caves (3°14' N, 101°41' E), a limestone massive with its maximum height at 304 m above sea level, is the southernmost tower karst in Peninsular Malaysia, as well as in the Asia mainland. It is perhaps the best-known limestone hill in the country, renowned for its temple cave and the Thaipusam festival. This tower karst is located 11 km northeast of Kuala Lumpur City. The close proximity to the capital city makes it convenient to both local and foreign visitors. In the early days, this tower karst was surrounded by dense forest, and wildlife including big mammals like tigers and bears often visited and used the caves at ground level (Wycherley 1971). There was already some small-scale guano extraction from the caves by Chinese farmers in the 1860s (Yussof 1997). However, Batu Caves only became known to the larger community in 1879, through the reports by Daly (1879) and Hornaday (1879, 1885). The Sri Subramaniar Swamy Temple was then established in 1891.

Henry Nicholas Ridley, Director of the Botanic Gardens in Singapore, conducted the first extensive scientific exploration of Batu Caves and its surrounding area. He visited Batu Caves in 1889, 1896, 1897, 1908 and 1920 (Wycherley 1972), when he collected botanical, zoological and some archaeological samples, particularly from the caves. The bryophyte samples collected by Ridley, mainly mosses, were later studied and reported in Dixon's 1924 and 1926 accounts of Malayan mosses. Besides a new moss species, *Endotrichella planomarginat*a published by Dixon in 1924. Dixon identified another 19 different moss species from Ridley's collections, which he then incorporated into his moss checklist of the Malay Peninsula (Dixon 1926). The first liverwort record from Batu Caves was not by Dixon nor from Ridley's collections, but of the thalloid liverwort, *Cyathodium cavernarum* Kunze ex Lehm., collected and studied by Lang (1905). According to Lang (1905),

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this thalloid liverwort was present in abundance, growing on the dim cave walls and floor. This species is still present in Batu Caves and can be found in the Temple Cave – the most famous cave where the Sri Subramaniar Swamy Temple is located, but in a very small population and only clinging to the higher and wetter part of the wall at the cave's entrance.

Wycherley (1972) added eight additional moss species or names to Dixon's 1926 record, some of which were based on collections by collectors after Ridley. Later, Mohamed (1987) listed a total of 76 moss species for Selangor's limestone hills (Batu Caves, Bukit Takun and Anak Bukit Takun), without specifying which records were represented on Batu Caves. In the same account, Mohamed (1987) provided a general synopsis for the diversity and ecology of mosses on limestone hills in Peninsular Malaysia. Since then, there were only infrequent and sporadic unreported collecting activities at Batu Caves, mainly focused on the area near to the Temple Cave but not beyond that.

Recent information on the physical and natural history of Batu Caves include accounts by Moseley *et al.* (2012), Yasamin *et al.* (2012) and Kiew (2014). However, none included bryophytes for which there was still no comprehensive checklist. Most historical bryophyte samples were obtained from the foothills or areas near to the main temple or Temple Cave, meaning that large parts of this tower karst, especially the higher elevations, remained unexplored. In addition, since Ridley's last visit, Batu Caves and its surrounding area have undergone major changes. It is now surrounded by industrial-residential areas and has become a habitat island. Before 1981, the western flank of the hill had been partly quarried, and the foothill area of Batu Caves is constantly under the pressure from further development, which threatens the geology and its role as a natural system sustaining the various life forms that inhabit this karst outcrop (Zubaid 2020). Therefore, in 2019, a large-scale biodiversity survey was conducted in the hope of documenting the changes and providing a more comprehensive account of the bryophyte diversity present on this karst system.

MATERIALS AND METHODS

Most of the materials reported in this study were collected during 2019 as part of the Batu Cave Scientific Expedition organized by Malaysian Cave and Karst Conservancy (MCKC). Between November 2018 and March 2020, several sampling trips were made to different parts of Batu Caves complex (Table 1). Most of the areas visited are still covered by pristine vegetation or vegetation with minimal disturbance, except for the trip on 8 December 2018, made specifically to the area damaged by fire in 2016, but is now covered by many fast-growing or invasive plant species. The elevation covered during this scientific expedition ranged from the foothills at about 50 m elevation to the summit of the tower karst at about 300 m. Identification of all samples was conducted at the Herbarium of Universiti Malaya (KLU) with reference to existing botanical literature and verified herbarium materials. All specimens are deposited in KLU with duplicates distributed to other local and oversea herbaria. Besides the recently acquired materials, earlier collections from Batu Caves deposited in KLU were examined and re-determined. These specimens were mostly collected between the 1960s until early 2000s, from the Temple Cave and its surroundings, by different collectors including S. Hindon, P.S. Camara, S.C. Chin and M.E.D. Poore.

Table 1. Collection number and collection sites for specimens collected during the 2019 Batu Cave Scientific Expedition. All specimens were collected by the first and second author and deposited in KLU.

Collection number	Information on the collection site and date of visit
10279	The area behind the Ayyappa Temple, adjacent to the Sunway Batu Cave Residency Area, 03°14'48" N, 101°41'23" E; 22 November 2018.
10280–10320	Ridges and valleys adjacent to Fig Tree Cave, ascending from the Gua Damai Extreme Park, 03°14'51" N, 101°41'18" E; 28 November 2018.
10321–10383	Bukit Batu Putih area, ascending from Kampung Melayu Wira Damai, between 03°14'46" N, 101°41'23" E to 03°14'49" N, 101°41'19" E; 6 December 2018.
10384–10397	Regenerated area, destroyed by fire in February 2016, now densely covered by fast-growing or invasive species, ascending from Bolton Industrial Park; 8 December 2018.
10398–10443	Lower slope to the west of Dark Cave, towards Gua Belah, the area between 03°14'18" N, 101°40'37" E to 03°14'20" N, 101°41'00" E; 13 December 2018.
10444–10486	Lower slope to the west of Dark Cave, Gua Belah, 03°14'19" N, 101°40'56" E; 3 January 2019.
10487–10524	Lower slope facing the Sunway Batu Caves Residency Area, ascending from the playfield, 03°14'21" N, 101°41'30" E to 03°14'45" N, 101°41'05" E; 10 January 2019
10525–10535	An area adjacent to Gua Pandan, 03°14'37" N, 101°41'06" E; 24 April 2019.
10536–10538	An area adjacent to Gua Pandan, 03°14'28" N, 101°41'14" E; 25 June 2019.
10539–10569	Summit and near summit area to the east of Bukit Batu Putih, ascending from Kampung Melayu Wira Damai, 03°14'44" N, 101°41'19" E; 8 August 2019.
10561–10565	The area between the Temple Cave and Cistern Cave, lower slope to the east of the steps to Temple Cave; 10 March 2020.
10566	Vicinity of the Temple Cave; 10 March 2020.

RESULTS AND DISCUSSION

Bryophyte diversity on Batu Caves

A total of 56 bryophyte species is here reported for Batu Caves. Of these, there are 16 liverwort (Marchantiophyta) species in nine genera and four families, and 40 moss (Bryophyta) species in 29 genera and 16 families (Table 2). The total number of mosses represents 54.8% of the limestone moss flora (Mohamed 1987) and 7.6% total moss flora (Yong *et al.* 2013) of Peninsular Malaysia. The moss flora of Batu Caves is comparable to other karst areas in Peninsular Malaysia. It is richer than Gunung Kanthan (Kiew *et al.* 2014) and Taman Rimba Kenong (Damanhuri *et al.* 2007), but less diverse than Gunung Senyum (Table 2). However, the report of Gunung Senyum (Norhazrina *et al.* 2019) included a large number of Calymperaceae species, a family known to be diverse in the humid lowland forest, but with few associated with karst habitats (Mohamed 1987).

Lejeuneaceae is by far the most speciose liverwort family, as well as the most diverse bryophyte family encountered in Batu Caves. Whereas the other liverwort families are each represented by a single species. Among the mosses, Fissidentaceae is the most diverse moss family in Batu Caves represented by six species. This is followed by Hypnaceae, Pottiaceae and Thuidiaceae, each represented by five species. Members of Fissidentaceae,

Hypnaceae, Pottiaceae and Thuidiaceae are usually well represented on limestone or karst habitats as noted in Mohamed (1987), and other reports pertaining to karst habitats (e.g., Yong *et al.* 2002; Damanhuri *et al.* 2007; Norhazrina *et al.* 2019) (Table 2). On Batu Caves, members of these families are often encountered and where present are usually in abundance and dominate the habitats.

Neckeraceae is another moss family that has been described as dominant with many members occurring in karst habitats (Mohamed 1987). However, this family is less diverse and uncommon on Batu Caves compared to other karst hills (Table 2). Members of Neckeraceae are generally of larger plant size, and possibly have a higher demand for moisture. On Batu Caves, Neckeraceae species are only present at specific locations with high humidity. Even then, individuals of *Pinnatella kuehliana* (Bosch and Sande Lac.) M.Fleisch. are represented by much smaller specimens. This suggests that conditions on Batu Caves are now drier in relative to the other karst hills in Peninsular Malaysia.

In 1926, Dixon recorded 20 different moss species based on Ridley's collection from the Batu Caves, of which eight were recollected during the recent survey. However, the names reported in Dixon (1926) are partly outdated while some are dubious records. Ridley collected at a time when Batu Caves was still surrounded by a vast tract of lowland forest, where the lowland forest extended up to the foot of the tower karst. Therefore, Ridley's collection may have included some of the typical lowland forest species that are not necessarily associated with karst habitat (Wycherley 1972). For example, *Chaetomitrium orthorrhynchum* (Dozy and Molk.) Bosch and Sande Lac., *Garovaglia elegans* (Dozy and Molk.) Bosch and Sande Lac. and *G. powelli* Mitt. var. *plano-marginata* (Dixon) During, that are known to be epiphytes in humid forest, but unknown in karst habitats (During 1977; Mohamed and Robinson 1991). Wycherley (1972) included two unpublished names in his list (viz., *Fissidens subamblyotis* Dixon and *Isopterygium laminatum* Dixon), and a doubtful record, *Bryum zollingeri* Duby, a synonym of *Rosulabryum billarderi* (Schwägr.) J.R. Spence, a highland species and is unknown below 500 m elevation (Eddy 1996). A revised species list based on Dixon (1926) and Wycherley (1972) with updated nomenclature changes is given in Appendix 1. Therefore, by taking into consideration the valid records from Dixon (1926), Wycherley (1972) and the recent survey, the total moss flora of Batu Caves now stands at 54 species, in 35 genera and 19 families.

New records for Peninsular Malaysia

Two liverwort species are reported in present study as new to Peninsular Malaysia. Both species are members of Lejeuneaceae from the genus *Cololejeunea*. The first species, *Cololejeunea pseudostipulata* (Schiffn.) Benedix, is morphologically related to *C. chinii* Tixier and *C. shimizui* N.Kitag. Together, they form the subgenus *Chondriolejeunea*. All three are known only from karst habitats, and are rare with limited records from South China, Indochina and Malesia (So and Zhu 1999; Kis and Pócs 2001). The new record, *C. pseudostipulata*, is a peculiar liverwort that is distinguished from the other congeneric species by its lighter green appearance, filiform and julaceous habit, strongly concave leaves, multipapillose to stellate leaf cells and spinose-ciliate leaf margins. A fine illustration of this species is given in Benedix (1953). It is a species restricted to Malesia and Melanesia. Prior to this report, this species had only been reported from Borneo (Sabah), New Guinea (West Irian) and New Caledonia (Kis and Pócs 2001; Pippo 1994; So and Zhu 1999).

The second new record is *Cololejeunea raduliloba* Steph. Unlike the former species, this species has a wide distributional range, present in both temperate and tropical areas, and is not restricted to karst habitat. Its distribution ranges from East Africa to East Asia at the north and to Australia and New Caledonia in the south (Zhu and So 2001). Morphologically, *C. raduliloba* is related to *C. schwabei* Herzog, an East Asian species, and can be distinguished from the latter species by having mitten-shaped leaf lobules almost parallel to the stem and

with a unicellular stylus. Also, the weakly developed trigones are sometimes visible on leaf cells. This feature is distinctive among the samples from Batu Caves and fits fairly well with the illustration in Mizutani (1961). Interestingly, this species was found epiphytically on other leafy liverwort species in the sample collected from Batu Caves.

Table 2. A summary of the bryophyte diversity present on a few karst hills in Peninsular Malaysia, including Batu Caves (present study), Gunung Kanthan (Kiew *et al.* 2014), Taman Rimba Kenong (Damanhuri *et al.* 2007) and Gunung Senyum (Norhazrina *et al.* 2019).

	Batu Caves, Selangor		**Gunung Kanthan, Perak**		**Taman Rimba Kenong, Pahang**		**Gunung Senyum, Pahang**	
	Genera	**Species**	**Genera**	**Species**	**Genera**	**Species**	**Genera**	**Species**
Mosses								
Bartramiaceae	1	1					1	1
Brachytheciaceae	1	1			1	1	1	1
Bryaceae	1	2	1	1	1	1	1	1
Calymperaceae	1	2	1	4	1	2	6	19 + 1 subsp.
Entodontaceae	1	1						
Erpodiaceae	1	1						
Fissidentaceae	1	6	1	5	1	4	1	9
Hypnaceae	5	5	3	4	5	7	2	6
Leskeacae	1	1						
Leucobryaceae	1	1			1	1		
Leucomiaceae							1	1
Meteoriaceae	2	2	2	2	2	3	1	1
Neckeraceae	3	4	2	4	3	8	4	6
Orthotrichaceae							1	1
Pilotrichaceae							1	1
Plagiotheciaceae							1	1
Pottiaceae	5	5	2	2	3	3	3	3
Pylaisiadelphaceae	1	1	1	1			2	6
Sematophyllaceae	2	2			2	2	5	5
Thuidiaceae	2	5	1	2	2	4	1	2
Total mosses	**29**	**40**	**14**	**25**	**22**	**36**	**32**	**64 + 1 subsp**
Liverworts								
Cyathodiaceae	1	1						
Frullaniaceae	1	1						
Lejeuneaceae	6	13	5	5				
Lophocoleaceae	1	1						
Total liverworts	**9**	**16**	**5**	**5**	**–**	**–**	**–**	**–**
Total bryophytes	**38**	**56**	**19**	**30**	**22**	**36**	**32**	**64 + 1 subsp.**

Microhabitats play an important role

Karst landscape is always an interesting location for bryophytes, because it provides a wide range of habitats or niches that sustain different bryophyte and plant species (Wycherley 1972; Mohamed 1987). The highly permeable limestone rocks offer various types of surfaces for the plants to grow on. The different steepness and orientation of rock faces influence the drainage pattern, air movement, accumulation of nutrients and the exposure to the sun during the whole or part of the day or year. Sites with different degrees of wetness and dryness, as well as soil with pH ranging from basic to acidic but generally poor in aluminium (Hutchinson 1968) are present on different part of the karst. Thus, a wide range of environmental conditions occurs on one karst hill and are available to different plant species.

In Batu Caves, acidic soil or peat soil is exceptionally common at the summit area (at elevation 300 m). The summit visited during this survey is more of a small plateau about 20–30 m radius. It is dominated by small to medium-sized trees, mostly microphylls and somewhat sclerophyllous, with canopy at about 3–4 m from the ground. The endemic fan palm, *Maxburretia rupicola* (Ridl.) Furtado is very common and abundant here. Slender and sharp pointing rocks due to weathering are common, but they are generally low and small. The summit plateau is not absolutely level but is a little undulating or jagged at some parts. Peat soil is common where humus accumulated and is more effective in retaining water, thus is the perfect substrate for many bryophyte species. Here, bryophytes grow profusely and form an extensive mat covering the ground, rocks and tree bases. Epiphytic bryophytes are also common and often densely cover the lower half of the tree trunks or low branches. In most other areas visited during the expedition, epiphytic species are rarely encountered and are few in abundance. A total of six liverworts and nine moss species were recorded on this summit plateau, with a number of them confined to this location. They include *Aerobryopsis longissima* (Dozy and Molk.) M.Fleisch., *Calymperes* cf. *moluccense* Schwägr., *Frullania gracilis* (Reinw., Blume and Nees) Gottsche, Lindenb. and Nees, *Lejeunea tuberculosa* Steph., *Leucobryum aduncum* Dozy and Molk. var. *scalare* (Müll. Hal. *ex* M.Fleisch.) A.Eddy, *Meiothecium microcarpum* (Harv.) Mitt., and *Papillidiopsis malayana* (Dixon) B.C.Tan.

Besides the summit plateau, the humid cave mouth is always an interesting habitat for many bryophytes. The constantly dripping water, drained from the higher elevation of the hill, moisten the rock surfaces and create perfect conditions for many species. The following species are often present at the brighter part of the cave mouth at Batu Caves: *Claopodium prionophyllum* (Müll. Hal.) Broth., *Ectropotheciella decrescens* (Sande Lac.) M.Fleisch., *Floribundaria floribunda* (Dozy and Molk.) M.Fleisch., *Heteroscyphus zollingeri* (Gottsche) Schiffn. and *Taxiphyllum taxirameum* (Mitt.) M.Fleisch. However, species like *Cyathodium cavernarum* Kunze ex Lehm., *Fissidens ceylonensis* Dozy and Molk., *Philonotis hastata* (Duby) Wijk and Marg. and *Pelekium bifarium* (Bosch and Sande Lac.) M.Fleisch. tend to occupy more shaded areas. Among these, *Cyathodium cavernarum* Kunze *ex* Lehm. is apparently the only species that can tolerate deep shade. A substantial population was found growing on rock surfaces inside the Pandan Cave at a place with constant dripping water and sufficient sunlight that reached the plant through a tiny sky-light and only available for a short period of the day.

Species of conservation importance

The fact that karst limestone hills harbour a unique set of flora does not apply only to flowering plants. Our findings show that bryophytes also exhibit a few rarities. One of them includes *Erpodium biseriatum* (Austin) Austin, a moss species reported from Peninsular Malaysia by Manuel (1981), but without any detail of its locality nor any herbarium sample. It is from the recent survey, the occurrence of this species in Peninsular Malaysia is confirmed, and Batu Caves is thus far the only known locality that houses this species in Peninsular Malaysia. Cheah and Yong (2020) carried out a conservation assessment for this

species and categories its status in Peninsular Malaysia as Critically Endangered under the IUCN criteria, in view of its single locality, sparse population and the high level of threat due to the pressures of urban development and lack of legal protection and enforcement.

Two other moss species collected during the Batu Caves Scientific Expedition, namely *Erythrodontium julaceum* (Hook. ex Schwägr.) Paris and *Hymenostylium recurvirostrum* (Hedw.) Dixon are rare in Peninsular Malaysia. Both species were only collected for the second time in Peninsular Malaysia after the first report from Taman Rimba Kenong (Damanhuri *et al.* 2007). *Hymenostylium recurvirostrum* is a calcicolous species confined to limestone hills. On Batu Caves, this species is only known to occur on a limestone boulder at the entrance of Temple Cave. Much like *H. recurvirostrum*, epiphytic *Erythrodontium julaceum* was only collected from an area near to the Temple Cave, both of which are prone to disturbance due to the influx of tourists.

In terms of global perspective, liverwort species such as *Cololejeunea chinii* Tixier, *C. pseudostipulata* (Schiffn.) Benedix and *Dactylophorella muricata* (Gottsche) R.M. Schust. are all regarded as rare species as they are found mostly in limestone karst areas. The discovery of *Cololejeunea pseudostipulata*, a new record for Peninsular Malaysia, further affirms that the Batu Caves complex is an important botanical site with high endemism and rarity. However, there has been a noticeable decline in population size of the luminous thalloid liverwort, *Cyathodium cavernarum* Kunze *ex* Lehm., particularly in the Temple Cave, assuming that Lang (1905) collected this species from the same locality more than a century ago. He noted, "…found growing in extensive patches on the walls and floors of a dimly lit limestone near Kuala Lumpur". The population found at the Temple Cave in the recent survey was sparse and scanty. It is therefore at utmost importance to conserve and protect this area through enforcement and strict laws to ensure the survival of these unique bryophytes.

CONCLUSION

This is the first attempt to sample bryophytes from as many microhabitats as possible from the Batu Cave massif. From 11 trips to different localities on Batu Caves, the survey resulted in 16 liverwort and 40 moss species, totalling to 56 bryophyte species. It amply demonstrated that Batu Caves indeed has a rich bryophyte flora and could be nominated as a potential key site for limestone bryophyte conservation in Malaysia. These findings provide fundamental information for future comparative studies as well as further evaluations of species richness and bryophyte ecology on other limestone hills from similar climatic regions. Such a survey could also be the foundation for implementing a future environmental monitoring programme, to assess the impacts of various natural changes or anthropogenic disturbances on the growth and development of bryophytes on limestone hills without buffer zones. This is especially appropriate for a location like Batu Caves, where extensive development still continues in its foothills. It would be of definite interest to see if the bryophyte communities could survive another decade of unrelenting encroachment on Batu Caves.

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BRYOPHYTE CHECKLIST OF BATU CAVES

Each species is accompanied by information of the specimens studied, habitats and elevation range. '*' indicates species new to Peninsular Malaysia.

Liverworts (MARCHANTIOPHYTA)

CYATHODIACEAE

1. *Cyathodium cavernarum* Kunze *ex* Lehm.
   YKT and CYH 10446, 10537, 10538. And also represented by a specimen in KLU: *YKT 4759* [9 Dec 2003] collected from the Temple Cave. Epilithic; growing on limestone rocks and cave wall near the cave entrance, at elevation 200–230 m.

FRULLANIACEAE

1. *Frullania gracilis* (Reinw., Blume & Nees) Gottsche, Lindenb. & Nees
   YKT & CYH 10550. Epiphytic; growing on tree trunk, at elevation about 300 m.

LEJEUNEACEAE

1. *Cololejeunea chinii* Tixier
   YKT & CYH 10296, 10367, 10395, 10469, 10551, 10558. Epilithic; growing on limestone rocks and boulder, occasionally on thin humus layer over the rocks, at elevation 50–300 m.
2. **Cololejeunea pseudostipulata* (Schiffn.) Benedix
   YKT & CYH 10540, 10543, 10558. Epilithic; growing on limestone rocks and thin humus layer over the rocks, at elevation 200–300 m.
3. **Cololejeunea raduliloba* Steph.
   YKT & CYH 10293, 10295. Epilithic; growing on limestone rocks, at elevation about 150 m.
4. *Dactylophorella muricata* (Gottsche) R.M.Schust.
   YKT & CYH 10393, 10395, 10543. Epilithic; growing on limestone rocks and thin humus layer over the rocks, at elevation 180–230 m.
5. *Lejeunea anisophylla* Mont.
   YKT & CYH 10284, 10290, 10293, 10294, 10295, 10298, 10304, 10305, 10315, 10317, 10319, 10343, 10367, 10372, 10395, 10429, 10479. Epilithic and epiphytic; growing on limestone rocks, lateral roots over the rocks and thin humus layer over the lateral roots, at elevation 50–180 m.
6. *Lejeunea papilionacea* Steph.
   YKT & CYH 10429. Epilithic; growing on limestone rocks, at elevation about 100 m.
7. *Lejeunea patriciae* Schäf.-Verw.
   YKT & CYH 10295. Epilithic; growing on limestone rocks, at elevation about 150 m.
8. *Lejeunea tuberculosa* Steph.
   YKT & CYH 10550. Epiphytic; growing on tree trunk, at elevation about 300 m.
9. *Lopholejeunea nigricans* (Lindenb.) Schiffn.
   YKT & CYH 10300, 10303, 10308, 10311, 10317, 10361, 10365, 10407, 10408, 10417, 10434, 10438, 10439, 10440, 10479. Epilithic and epiphytic; growing on limestone rocks, thin soil layer over the limestone, lateral roots over the rocks and thin humus layer over the lateral roots, at elevation 50–150 m.
10. *Lopholejeunea subfusca* (Nees) Schiffn.
    YKT & CYH 10283, 10418, 10475. Epilithic; growing on limestone rocks, at elevation 100–150 m.
11. *Spruceanthus planiusculus* (Mitt.) X.Q.Shi, R.L.Zhu & Gradst.
    YKT & CYH 10281, 10282, 10284, 10291, 10293, 10294, 10309, 10313, 10553. Epilithic; growing on limestone rocks and crevices between rocks, at elevation 70–300 m.

12. *Thysananthus humilis* (Gottsche) Sukkharak & Gradst.
YKT & CYH 10280, 10283, 10310, 10367, 10390, 10395, 10487, 10463. Epilithic; growing on limestone rocks and crevices between rocks, at elevation 70–200 m.
13. *Thysananthus repletus* (Taylor) Sukkharak & Gradst.
YKT & CYH 10466, 10469, 10551, 10553. Epilithic; growing on boulder and thin humus layer over the limestone rocks, at elevation 50–300 m.

LOPHOCOLEACEAE
1. *Heteroscyphus zollingeri* (Gottsche) Schiffn.
YKT & CYH 10299, 10320, 10478. Epilithic; growing on limestone rocks, at elevation 50–160 m.

Mosses (BRYOPHYTA)

BARTRAMIACEAE
1. *Philonotis hastata* (Duby) Wijk & Marg.
YKT & CYH 10336, 10497, 10512, 10514, 10525, 10565. And also represented by specimens in KLU: Hindon 2, 8c [16 Jun 1982], Camara 1023 [9 Dec 2005], collected from the Temple Cave and its foothill area. Epilithic; growing on limestone rocks, thin soil layer over the limestone rocks and old fabric encountered at the landfill, at elevation 50–120 m.

BRACHYTHECIACEAE
1. *Rhynchostegium celebicum* (Sande Lac.) A.Jaeger
YKT & CYH 10490, 10519. Epilithic; growing on limestone rocks, in shaded area at elevation 80–100 m.

BRYACEAE
1. *Bryum apiculatum* Schwägr.
YKT & CYH 10565. And also represented by specimens in KLU*: Camara 1010, 1014, 1021* [9 Dec 2005], collected from an area nearby Temple Cave. Epilithic; growing on limestone rocks, at elevation 60–100 m.
2. *Bryum clavatum* (Schimp.) Müll. Hal.
This species is not encountered in the recent survey but represented by specimens in KLU: *Hindon 6* [16 Jun 1982] and *Camara 1021* [9 Dec 2005], collected from an area nearby Temple Cave at elevation about 60 m.

CALYMPERACEAE
1. *Calymperes* cf. *moluccense* Schwägr.
YKT & CYH 10550. Epiphytic; growing on tree trunk, at elevation about 300 m. Unlike the typical form of the species, the leaf laminal cells of this sample are moderately thick-walled with quadrate lumens.
2. *Calymperes taitense* (Sull.) Mitt.
YKT & CYH 10297, 10312, 10341, 10347, 10356, 10358, 10364, 10366, 10374, 10376, 10379, 10391, 10436, 10527, 10533, 10562. Epilithic; growing on limestone rocks and thin humus layer over the rocks, at elevation 100–300 m.

ENTODONTACEAE
1. *Erythrodontium julaceum* (Hook. ex Schwägr.) Paris
This species is not encountered in the recent survey but represented by specimens in KLU: *Camara 1007, 1009, 1013, 1016* [9 Dec 2005], collected from an area nearby Temple Cave at elevation about 60 m.

ERPODIACEAE

1. *Erpodium biseriatum* (Austin) Austin
   YKT & CYH 10285, 10289, 10371. Epilithic; growing on limestone rocks, in shaded area at elevation 130–150 m.

FISSIDENTACEAE

1. *Fissidens bogoriensis* M.Fleisch.
   YKT & CYH 10331, 10541. Epilithic; growing on thin soil over the limestone, at elevation 120–200 m.
2. *Fissidens ceylonensis* Dozy & Molk.
   YKT & CYH 10327, 10353, 10354, 10464, 10471, 10516, 10518. Epilithic; growing on limestone rocks and boulder, at elevation 50–200 m.
3. *Fissidens crassinervis* Sande Lac.
   YKT & CYH 10439. Epilithic; growing on thin soil layer over the limestone rocks, at elevation about 100 m.
4. *Fissidens hollianus* Dozy & Molk.
   YKT & CYH 10298, 10306, 10323, 10325, 10328, 10329, 10337, 10339, 10344, 10359, 10360, 10362, 10365, 10367, 10368, 10369, 10381, 10385, 10386, 10392, 10395, 10427, 10429, 10432, 10435, 10440, 10484, 10507, 10548. And also represented by a specimen in KLU: *Hindon 25* [16 Jun 1982], collected from an area nearby Temple Cave. Epilithic; growing on limestone rocks, at elevation 50–250 m.
5. *Fissidens oblongifolius* Hook.*f.* & Wilson
   YKT & CYH 10296, 10307, 10349, 10352, 10373, 10378, 10508, 10539, 10540, 10542, 10549, 10551, 10554, 10558. And also represented by a specimen in KLU: *SC Chin 356* [25 Sep 1970], collected from an area nearby to the Temple Cave. Epilithic; growing on limestone rocks, boulder and thin humus layer over the limestone rocks, at elevation 120–300 m.
6. *Fissidens zollingeri* Mont.
   YKT & CYH 10331, 10439. Epilithic; growing on thin soil over the limestone rocks, at elevation 100–120 m.

HYPNACEAE

1. *Ectropotheciella decrescens* (Sande Lac.) M.Fleisch.
   YKT & CYH 10456, 10457, 10458, 10528. Epilithic; growing on limestone rocks and wet rocks near the cave mouth, at elevation 100–200 m.
2. *Ectropothecium dealbatum* (Reinw. & Hornsch.) A.Jaeger
   YKT & CYH 10335, 10437, 10483, 10504. Epilithic; growing on limestone rocks and soil, at elevation 50–120 m.
3. *Isopterygium bancanum* (Sande Lac.) A.Jaeger
   YKT & CYH 10561. And also represented by specimens in KLU: *Hindon 22* [16 Jun 1982], *Camara 1017* [9 Dec 2005], collected from the Temple Cave. Epilithic; growing on limestone rocks and wet rock near cave wall, at elevation 50–60 m.
4. *Taxiphyllum taxirameum* (Mitt.) M.Fleisch.
   YKT & CYH 10288, 10290, 10301, 10389, 10399, 10401, 10403, 10404, 10405, 10408, 10415, 10420, 10421, 10424, 10456, 10482, 10509, 10513, 10523, 10535. It is also represented by a specimen in KLU: *Hindon 7a* [16 Jun 1982], collected from an area nearby Temple Cave. Epilithic; growing on limestone rock and rocks near the cave mouth, at elevation 50–200 m.
5. *Vesicularia montagnei* (Schimp.) Broth.
   This species is not encountered in the recent survey but represented by specimens in KLU: *Hindon 12, 19, 25* [16 Jun 1982], *Camara 1014* [9 Dec 2005], collected from an area nearby Temple Cave at elevation about 60 m.

LESKEACEAE

1. *Claopodium prionophyllum* (Müll. Hal.) Broth.
   YKT & CYH 10458, 10473. Epilithic; growing on limestone rocks near the cave mouth, at elevation 50–200 m.

LEUCOBRYACEAE

1. *Leucobryum aduncum* Dozy & Molk. var. *scalare* (Müll. Hal. *ex* M.Fleisch.) A.Eddy
   YKT & CYH 10552. Epilithic; growing on limestone rocks, at elevation about 300 m.

METEORIACEAE

1. *Aerobryopsis longissima* (Dozy & Molk.) M.Fleisch.
   YKT & CYH 10550, 10551, 10556, 10559, 10560, 10561, 10565, 10567. Epiphytic; growing on tree trunk and base, and thin humus layer over the limestone rocks, at elevation about 300 m.
2. *Floribundaria floribunda* (Dozy & Molk.) M.Fleisch.
   YKT & CYH 10473, 10474, 10480. Epilithic; growing on limestone rocks, at elevation about 50 m.

NECKERACEAE

1. *Caduciella mariei* (Besch.) Enroth
   YKT & CYH 10300, 10302, 10303, 10308, 10314, 10333. Epiphytic and epilithic; growing on tree trunk and limestone rocks, at elevation 120–150 m.
2. *Neckeropsis lepineana* (Mont.) M.Fleisch.
   YKT & CYH 10530. Epilithic; growing on limestone rocks, at elevation about 100 m.
3. *Pinnatella kuehliana* (Bosch & Sande Lac.) M.Fleisch.
   YKT & CYH 10291, 10292, 10393, 10431, 10476, 10515. Epilithic; growing on limestone rocks, at elevation 50–180 m.
4. *Pinnatella mucronata* (Bosch & Sande Lac.) M.Fleisch.
   YKT & CYH 10369, 10442. Epiphytic and epilithic; growing on tree trunk and limestone rocks, at elevation 100–150 m.

POTTIACEAE

1. *Barbula indica* (Hook.) Spreng.
   This species is not encountered in the recent survey but represented by specimens in KLU: *Hindon 1, 4a, 9a* [16 Jun 1982], Camara 1014 [9 Dec 2005], collected from an area nearby Temple Cave, at elevation about 60 m.
2. *Chionoloma sarawakense* (Dixon) Alonso, Cano & Jiménez
   YKT & CYH 10307, 10364, 10406, 10410, 10412, 10428, 10491, 10542, 10564, 10565. Epilithic; growing on limestone rocks, at elevation 100–300 m.
3. *Hyophila involuta* (Hook.) A.Jaeger
   YKT & CYH 10279, 10425, 10514. And also represented by specimens in KLU: *Hindon 8b, 10* [16 Jun 1982], Camara 1021 [9 Dec 2005], collected from an area nearby Temple Cave. Epilithic; growing on limestone rocks, at elevation 50–100 m.
4. *Hymenostylium recurvirostrum* (Hedw.) Dixon
   YKT & CYH 10566. And also represented by specimens in KLU: *Hindon 8a, 9c* [16 Jun 1982], collected from the Temple Cave. Epilithic; growing on limestone rocks near the entrance of Temple Cave, at elevation about 150 m.
5. *Trichostomum brachydontium* Bruch
   YKT & CYH 10351, 10370, 10502, 10506, 10555. Epilithic; growing on limestone rocks and boulder, at elevation 50–300 m.

PYLAISIADELPHACEAE

1. *Taxithelium nepalense* (Schwägr.) Broth.
   YKT & CYH 10318, 10531. Epiphytic; growing on liana and rotten logs, at elevation 100–150 m.

SEMATOPHYLLACEAE

1. *Meiothecium microcarpum* (Harv.) Mitt.
   YKT & CYH 10569. Epiphytic; growing on tree branches, at elevation about 300 m.
2. *Papillidiopsis malayana* (Dixon) B.C.Tan
   YKT & CYH 10557, 10561, 10563, 10564, 10566. Epilithic; growing on limestone rocks and thin humus layer over the limestone rocks, at elevation about 300 m.

THUIDIACEAE

1. *Pelekium bifarium* (Bosch & Sande Lac.) M.Fleisch.
   YKT & CYH 10304, 10321, 10343, 10346, 10348, 10388, 10394, 10422, 10423, 10440, 10445, 10453, 10468, 10472, 10478, 10482, 10486, 10495, 10496, 10564. And also represented by specimens in KLU: *Hindon 7, 14, 17d, 18* [16 Jun 1982], collected from area nearby to the Temple Cave. Epilithic and epiphytic; growing on limestone rocks, soil and exposed roots, at elevation 50–210 m.
2. *Pelekium gratum* (P.Beauv.) A.Touw
   YKT & CYH 10401, 10422. Epilithic; growing on limestone rocks, at elevation 80–100 m.
3. *Pelekium velatum* Mitt.
   YKT & CYH 10330, 10419, 10472, 10503, 10517. And also represented by specimens in KLU: *Hindon 7c, 15, 21, 23* [16 Jun 1982], *Camara 1012, 1019* [9 Dec 2005], collected from an area nearby Temple Cave. Epilithic; growing on limestone rocks and soil, at elevation 50–120 m.
4. *Thuidium plumulosum* (Dozy & Molk.) Dozy & Molk.
   YKT & CYH 10481, 10493. And also represented by a specimen in KLU: *Poore 805* [16 Jul 1961], collected from the foothill of the Temple Cave. Epilithic; growing on limestone rocks, at elevation 50–90 m.
5. *Thuidium pristocalyx* (Müll. Hal.) A.Jaeger
   YKT & CYH 10510, 10563. Epilithic; growing on limestone rocks, at elevation about 50 m.

APPENDIX 1.
List of mosses reported by Dixon (1926) and Wycherley (1972) for Batu Caves.
Species not encountered during the recent survey were denoted with '+'.

Bryum coronatum Schwägr.—Wycherley (1972: 31).
+*Chaetomitrium orthorrhynchum* (Dozy & Molk.) Bosch & Sande Lac.—Dixon (1926: 28); Wycherley (1972: 31).
+*Ectropothecium incubans* (Reinw. & Hornsch.) A.Jaeger *f. scaberula* M.Fleisch. —Wycherley (1972: 31).
Floribundaria floribunda (Dozy & Molk.) M. Fleisch.—Dixon (1926: 23); Wycherley (1972: 31)
+*Garovaglia elegans* (Dozy & Molk.) Bosch & Sande Lac. [syn. *Garovaglia aristata* Bosch & Sande Lac.]—Dixon (1926: 23); Wycherley (1972: 31).
+*G. powelli* Mitt. var. *plano-marginata* (Dixon) During [syn. *Endotrichella plano-marginata* Dixon]—Dixon (1924: 235, syntype of *E. plano-marginata* from Batu Caves); Dixon (1926: 23); Wycherley (1972: 31).
+*Isopterygium albescens* (Hook.) A.Jaeger—Dixon (1926: 33); Wycherley (1972: 31).
Isopterygium bancanum (Sande Lac.) A.Jaeger—Dixon (1926: 33); Wycherley (1972: 31).
+*Isopterygium laxissimum* Cardot—Dixon (1926: 33); Wycherley (1972: 31).
+*Leucophanes candidum* (Schwägr.) Lindb.—Dixon (1926: 8); Wycherley (1972: 31).
Meiothecium microcarpum (Harv.) Mitt.—Dixon (1926: 37); Wycherley (1972: 31).
+*Meteorium polytrichum* Dozy & Molk. [syn. *M. miquelianum* (Müll. Hal.) M.Fleisch.] —Dixon (1926: 23); Wycherley (1972: 32).
+*Neckeropsis gracilenta* (Bosch & Sande Lac.) M.Fleisch.—Dixon (1926: 23); Wycherley (1972: 32).
Neckeropsis lepineana (Mont.) M.Fleisch.—Wycherley (1972: 32).
Pelekium bifarium (Bosch & Sande Lac.) M.Fleisch. [syn. *Thuidium bifarium* Bosch & Sande Lac.]—Dixon (1926: 29); Wycherley (1972: 32).
Pelekium velatum Mitt.—Dioxn (1926: 29); Wycherley (1972: 32).
Pinnatella kuehliana (Bosch & Sande Lac.) M.Fleisch.—Dixon (1926: 25); Wycherley (1972: 32).
Pinnatella mucronata (Bosch & Sande Lac.) M.Fleisch. [was reported as *P. anacamptolepis* (Müll. Hal.) Broth. based on Ridley 638, which was a case of wrong determination according to Mohamed & Abdullah (1988)]—Dixon (1926: 25); Wycherley (1972: 32).
+*Syrrhopodon albovaginatus* Schwägr.—Wycherley (1972: 32, orthographical error, was listed as '*albo-maginatus*').
+*Vesicularia dubyana* (Müll. Hal.) Broth.—Dixon (1926: 36); Wycherley (1972: 32).
+*Vesicularia miquelii* (Sanda Lac.) M.Fleisch.—Wycherley (1972: 32).
Vesicularia montagnei (Schimp.) Broth.—Dixon (1926: 36); Wycherley (1972: 32).
+*Vesicularia reticulata* (Dozy & Molk.) Broth.—Dixon (1926: 36); Wycherley (1972: 32).
+*Wilsoniella decipiens* (Mitt.) Alston [syn. *Wilsoniella acutifolia* Broth., nom. nud. & *W. pellucida* (Wils) Müll. Hal.]—Dixon (1926: 3); Wycherley (1972: 32).

The following two names were not validly published and the third was a highland species unlikely to present in Batu Caves, thus been excluded from the Batu Caves record until further verification:

Fissidens subamblyotis Dixon, nom. illeg.—Wycherley (1972: 31).
Isopterygium laminatum Dixon, nom. illeg.—Wycherley (1972: 31).
Rosulabryum billarderi (Schwägr.) J.R.Spence [syn. *Bryum zollingeri* Duby]—Wycherley (1972: 31).