

Vascular plants on the recovery burn site of Batu Caves, Selangor, Malaysia

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Abstract: In 2016, a forest fire on Batu Caves laid bare an extensive area of the massif on the northeast hill face. Three years after the incident, 200 plant species in 71 families were recorded from the burned area. Comparison with former botanical checklists from the whole undisturbed complex of Batu Caves indicated significant vegetation recovery in the burned areas despite changes in the forest environment. Two spatially distinct recovery processes could be observed. The most species rich area was dominated by *Macaranga tanarius* and *Carica papaya*, and its revegetation relied on seed dispersal. The second was dominated by *Pterolobium densiflorum*, and relied essentially on vegetative regrowth. The occurrence of clumps of young *Arenga westerhoutii* palm was probably the result of thermal scarification during the fire.

Keywords: forest fire, limestone hill ecosystem, succession

INTRODUCTION

Batu Caves or Gua Batu (3°14'N, 101°41'E) is situated 11 km northeast of Kuala Lumpur (Kiew 2014). It is a massive, isolated limestone karst, towering up to 329 m high above the Klang Valley plain with an extensive cave system (Lim and Yussof 2009).

Batu Caves is the most studied limestone hill and cave ecosystem in Malaysia as well as in Southeast Asia (Moseley *et al.* 2012). The extensive research on Batu Caves is certainly due to its proximity to Kuala Lumpur. H.N. Ridley was among the pioneer researchers who conducted studies on Batu Caves. His exhaustive exploration was published in 1898, 1899a, 1899b, 1907a, and 1907b. In these publications, Batu Caves was named as 'Caves Kwala Lumpur', 'Kwala Lumpur Caves', 'Selangor', 'Selangor Caves', 'Selangor Gua Batu' or 'Selangor Kuala Lumpur'. Chin (1977, 1979, 1983a, 1983b) provided a species list of vascular plants from limestone hills in Peninsular Malaysia based on research carried out for his Masters degree. Kiew (2014) compiled a checklist based on herbarium specimens and literature references that provided insight on the plant diversity of Batu Caves.

Batu Caves and its adjacent area have been increasingly exploited since 1800. Moseley (2014) and Daly (1879) reported hunting, establishment of the Sri Subramaniam Temple, guano mining, fruit plantations, rubber plantations and tin mines as the start of a progressive disappearance of wildlife and the associated lifestyle of indigenous (Temuan) people. Following urbanisation and illegal settlements with houses reaching up to the cave wall in places have further isolated Batu Caves from natural surroundings and ecological continuities. The absence of a forested buffer zone and possible open burnings in settlements increased the risks of fire propagation on the hill. Between 26th to 28th of February 2016, an accidental fire believed to be due to the burning of trash (Free Malaysia Today 2016) swept up the northeast hill face of Batu Caves and generated a cleared zone of 17 ha with an estimated perimeter of 2 km.

Many limestone plants are linked to specific and narrow microhabitats (Kiew 2019). Further ecological isolation through land use and development have made the vegetation increasingly vulnerable to disturbance, especially fire (Chin 1977) that has been identified and discussed as a major threat to the limestone flora on isolated karsts throughout Peninsular Malaysia (Chua *et al.* 2009). A botanical survey after a severe forest fire incident on on Gua Musang, Kelantan, limestone was initiated by Chin (1977). He found that the size of trees and the thickness of bark were important conditions for tree survival to fire events. He also discovered that many trees have a peculiar capacity to withstand fire, regrowing to their mature size and producing flowers in less than two years although they were burnt almost to the ground. Identifying the resilience of the various and distinct vegetation of massive karsts (Chin 1977) has become a main concern in a context of increasingly isolated flora and accelerated threats of forest fire. Botanical surveys after forest fire incidents remain infrequent in Malaysia and the present study is the first of this kind carried out for Batu Cave. It addresses the following questions: (a) what plants invade burned areas? (b) how does plant succession proceed? and (c) will the original vegetation be able to re-establish?

MATERIALS AND METHODS

A total of five surveys were carried out by the members of Flora Special Interest Group of the Malaysian Nature Society Selangor Branch in the burned and unburned areas of Batu Caves. Four survey sites in the burned area were selected: Lorong Siantan 3 towards the left side hill; at Nyamuk Wall; Lorong Siantan 3 towards the right side to the first hill top; Lorong Siantan 3 towards the right side to the second hill top. One survey of the unburned area at Gua Damai provided a comparison of species composition.

The botanical survey included vascular plants only. Plant data were collected accompanied by photographs. Identifications were executed chiefly in the field. For plants that could not be determined on the spot, leaves or small specimens were sampled for further study to verify either their genus or species name. The surveyed plants were listed and compared with the existing checklist by Kiew (2014).

RESULTS

A total of 200 species of *Lycopodiales*, *Polypodiales* and seed plants represented by 71 families were identified. Species (Table 1) and families (Table 2) are juxtaposed with the list of those identified by Kiew (2014).

Table 1. List of vascular plants from the burned area of Batu Caves compared with the checklist in Kiew (2014).

Survey on burned area of Batu Caves	Batu Caves checklist (Kiew 2014)
FERNS	
Aspleniaceae	
–	<i>Asplenium cheilosorum</i> Kunze ex Mett.
–	<i>Asplenium macrophyllum</i> Sw.
<i>Asplenium nidus</i> L.	–
<i>Asplenium polyodon</i> G. Forst.	<i>Asplenium polyodon</i> G. Forst.
–	<i>Asplenium vittaeforme</i> Cav.

Athyriaceae*Diplazium esculentum* (Retz.) Sw.*Diplazium esculentum* (Retz.) Sw.**Davalliaceae***Davallia denticulata* (Burm.f.) Mett. ex Kuhn –**Lomariopsidaceae**

–

Cyclopeltis crenata (Fee) C.Chr**Lygodiaceae***Lygodium longifolium* (Willd.) Sw.

–

Nephrolepidaceae*Nephrolepis biserrata* (Sw.) Schott

–

Nephrolepis falciformis J.Sm.*Nephrolepis falciformis* J.Sm.**Polypodiaceae**

–

Microsorium membranifolium (R.Br) Ching*Phymatosorus scolopendria* (Burm.f) Pic.Serm. –*Pyrrosia lanceolata* (L.) Farw.

–

–

Pyrrosia stigmosa (Sw.) Ching**Pteridaceae***Adiantum tenerum* Sw.*Adiantum tenerum* Sw.*Adiantum latifolium* Lam.

–

Adiantum malesianum Ghatak*Adiantum malesianum* Ghatak

–

Calciphlopteris alleniae (R.M. Tyron) Hesilyurt and H. Schneid.

–

Calciphylopteris ludens (Wall. ex Hook) Hesilyurt and H. Schneid.

–

Antrophyum parvulum Blume*Hemionitis arifolia* (Burm.f.) T. Moore*Hemionitis arifolia* (Burm.f.) T. Moore*Pteris ensiformis* L.*Pteris ensiformis* L.

–

Pteris venulosa Blume*Pteris vittata* L.*Pteris vittata* L.**Schizaeaceae**

–

Actinostachys inopinata (Selling) Reed**Selaginellaceae***Selaginella alutacia* Spring*Selaginella alutacia* Spring*Selaginella mayeri* Hieron*Selaginella mayeri* Hieron

–

Selaginella padangensis Hieron

Tectariaceae

Heterogonium pinnatum (Copel.) Holttum

–

Tectaria devexa (Kunze) Copel.

–

Tectaria quinquefida (Baker) Ching

Heterogonium pinnatum (Copel.) Holttum

Tectaria sp.

Tectaria devexa (Kunze) Copel.

Tectaria keckii (Loursson) C.Chr.

–

Thelypteridaceae

–

Amblovenatum opulentum J.P. Roux

–

Amphineuron immersum (Blume) Holttum

Amblovenatum opulentum J.P. Roux

Pronephrium triphyllum (Sw.) Holttum

GYMNOSPERMS

Podocarpaceae

Podocarpus nerifolius D.Don

–

Podocarpus nerifolius D.Don

Podocarpus polystachyus R.Br. ex Endl.

ANGIOSPERMS – DICOTYLEDONS

Acanthaceae

Asystasia gangetica (L.) T.Anderson

–

Hemigraphis glaucescens C.B.Clarke

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–

–

–

–

–

Justica uber C.B.Clarke

Pararuellia sumatrensis (C.B.Clarke) Bremek.
var. *ridleyi* (C.B.Clarke) Bremek.

Pseudoranthemum crenulatum (Lindl.) Radk.

Pseudoranthemum lilacinum Stapf

Ptyssiglottis kunthiana (Ness) B.Hansen

Rungia laxiflora C.B.Clarke

Actinidaceae

–

Saurauia pentapetala (Jack) Hoogland

Saurauia leprosa Korth,

Saurauia pentapetala (Jack) Hoogland

Amaranthaceae

Amaranthus blitum L.

–

Cyathula prostrata (L.) Blume

–

Anacardiaceae

Mangifera indica L.

–

–

Pistacia malayana M.R.Hend.

Annonaceae

<i>Ecosanthum congregatum</i> (King) Airy Shaw	<i>Ecosanthum congregatum</i> (King) Airy Shaw
–	<i>Goniothalamus macrophyllus</i> (Blume) Hook.f. and Thomson
–	<i>Polyalthia brunneifolia</i> J.Sinclair
<i>Polyalthia guabatuensis</i> I.M.Turner and Utteridge	–
–	<i>Polyalthia jenkinsii</i> (Blume) Hook.f. and Thomson
–	<i>Polyalthia obliqua</i> Hook.f. and Thomson
–	<i>Sageraea elliptica</i> (A.DC) Hook.f. and Thomson
<i>Trivalvaria macrophylla</i> (Blume) Miq.	<i>Trivalvaria macrophylla</i> (Blume) Miq.
<i>Uvaria grandiflora</i> Roxb. ex Hornem.	<i>Uvaria grandiflora</i> Roxb. ex Hornem.
<i>Uvaria javana</i> Dunal	<i>Uvaria javana</i> Dunal

Apocynaceae

<i>Alstonia scholaris</i> (L.) R.Br.	<i>Alstonia scholaris</i> (L.) R.Br.
–	<i>Alyxia angustifolia</i> Ridl.
–	<i>Alyxia pilosa</i> Miq.
<i>Alyxia reinwardtii</i> Blume	–
<i>Beaumontia murtonii</i> Craib	<i>Beaumontia murtonii</i> Craib
–	<i>Dischidia hirtusa</i> (Blume) Decne.
–	<i>Gymnema</i> sp.
<i>Heterostemma piperifolia</i> King and Gamble	<i>Heterostemma piperifolia</i> King and Gamble
–	<i>Hoya coriacea</i> Blume
–	<i>Hoya finlaysonii</i> Wigh
<i>Hoya verticilata</i> (Vahl.) G.Don. var. <i>citrina</i> (Ridl.) Veldkamp	<i>Hoya verticilata</i> (Vahl.) G.Don. var. <i>citrina</i> (Ridl.) Veldkamp
–	<i>Hunteria zeylanica</i> (Rezt.) Garden ex Thwaites
–	<i>Kopsia griffithii</i> King and Gamble
–	<i>Marsdenia ridleyi</i> P.I.Forst
<i>Marsdenia tinctoria</i> R.Br.	<i>Marsdenia tinctoria</i> R.Br.
–	<i>Secamone elliptica</i> R.Br.
<i>Tabernaemontana pauciflora</i> Blume	–
–	<i>Tabernaemontana peduncularis</i> Wall.
–	<i>Toxocarpus curtisii</i> King and Gamble

–	<i>Toxocarpus pauciflota</i> M.R.Hend.
–	<i>Tylophora flexuosa</i> R.Br.
Araliaceae	
<i>Schefflera oxyphylla</i> (Miq.) R.Vig.	<i>Schefflera oxyphylla</i> (Miq.) R.Vig.
<i>Trevesia palmata</i> (Roxb. ex Lindl.) Vis	–
Balsaminaceae	
–	<i>Impatiens ridleyi</i> Hook.f.
Begoniaceae	
–	<i>Begonia kingiana</i> Irmsch.
–	<i>Begonia phoeniogramma</i> Ridl.
Bignoniaceae	
–	<i>Radermachera glandulosa</i> (Blume) Miq.
<i>Spathodea campanulam</i> P.Beauv.	–
Boraginaceae	
–	<i>Ehretia timorensis</i> Decne.
Capparaceae	
–	<i>Capparis pubiflora</i> DC.
Caricaceae	
<i>Carica papaya</i> L.	–
Celastraceae	
–	<i>Euonymus javanicus</i> Blume
–	<i>Glyptopetalum quadrangulare</i> Prain ex King
–	<i>Loeseneriella cumingii</i> Laws.
–	<i>Maytenus curtisii</i> (King) Ding Hou
<i>Salacia macrophylla</i> Blume	<i>Salacia macrophylla</i> Blume
Chloranthaceae	
<i>Chloranthus erectus</i> Link	<i>Chloranthus erectus</i> Link
Clusiaceae	
–	<i>Garcinia murdochii</i> Ridl.
Compositae	
<i>Ageratum conyzoides</i> (L.) L.	–
<i>Bidens pilosa</i> L.	–
<i>Blumea balsamifera</i> (L.) DC.	–

Convovulaceae

- *Argyreia kunstleri* (Prain) Prain ex Oostrstr.
- *Erycibe rheedii* Blume
- *Lepistemon binectiferum* (Wall.) Kuntze

Cucurbitaceae

- *Bayabusua clarkei* (King) W.J. de Wilde
- Coccinia grandis* (L.) Voight
- Melothria pendula* L.
- *Momordica cochinchinensis* (Lour.) Spreng
- *Neosalsomitra clavigera* (Wall.) Hutch.
- *Scopellaria marginata* (Blume) W.J. de Wilde

Dilleniaceae

- *Dillenia excelsa* (Jack) Gilg
- Tetracera indica* (Christ.and Prain) Merr.
- Tertacera scandens* (L.) Merr.

Dipterocarpaceae

- *Anisoptera costata* Korth.
- Hopea dryobalanoides* Mig.
- Shorea sumatrana* (Slooten) Desch.

Ebenaceae

- Diospyros diepenhorstii* Miq
- *Diospyros kurzii* Hiern.
- Diospyros lanceifolia* Roxb.
- Diospyros wallichii* King and Gamble

Elaeocarpaceae

- *Elaeocarpus pedunculatus* Wall. ex Mast.

Erythroxylaceae

- Erythroxylum cuneatum* (Miq.) Kurz
- Erythroxylum cuneatum* (Miq.) Kurz

Euphorbiaceae

- *Cnesmone subpeltata* Ridl.
- Codiaeum variegatum* (L.) Rumph. ex A.Juss.
- Homalanthus populifolius* Graham
- *Homalanthus populneus* (Grisel.) Pax
- Macaranga depressa* (Müll.Arg) Müll.Arg.
- Macaranga hispida* (Blume) Müll.Arg.

Macaranga tanarius (L) Müll.Arg.
Mallotus dispar (Blume) Müll.Arg.
Mallotus repandus (Willd.) Müll.Arg
–
Trigonostemon villosus Hook.f.

Icacinaceae

Iodes ovalis Blume

Gentianaceae

Duplipetala pentanthera (C.B.Clarke) Thiv

–

–

Gesneriaceae

–

–

Microchirita caliginosa (C.B.Clarke) Y.Z.Wang

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–

Lamiaceae

Callicarpa angustifolia King and Gamble

–

Lauraceae

–

–

Litsea angulata Blume

Lecythidaceae

Barringtonia fusiformis King

Leguminosae

Archidendron jiringa (Jack) I.C.Nielsen

Bauhinia bidentata Jack

Derris elliptica (Wall.) Benth.

Derris trifoliata Lour.

Parkia speciosa Hassk.

Macaranga tanarius (L) Müll.Arg.

Mallotus dispar (Blume) Müll.Arg.

Mallotus repandus (Willd.) Müll.Arg

Sapium insigne (Royle) Benth.

Trigonostemon villosus Hook.f.

–

Duplipetala pentanthera (C.B.Clarke) Thiv

Fagraea carnosae Jack

Fagraea ceylanica Thunb.

Cyrtandra pendula Blume

Epithema parvibracteatum Hilliard and
B.L.Burtt

Microchirita caliginosa (C.B.Clarke) Y.Z.Wang

Monophyllaea hirticalyx Franch.

Monophyllaea horsfieldii R.Br.

Paraboea paniculata (Ridl.) B.I.Burtt.

Paraboea verticillata (Ridl.) B.I.Burtt.

Callicarpa angustifolia King and Gamble

Clerodendrum deflexum Wall.

Cryptocarya griffithiana Wight

Dehaasia pauciflora Blume

Litsea angulata Blume

Barringtonia fusiformis King

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–

Derris trifoliata Lour.

–

Pterolobium densiflorum Prain

Saraca thaipengensis Prain

Malvaceae

Durio zibethinus L.

Pentace triptera Mast.

–

Pterygota alata (Roxb.) R.Br.

Sterculia sp.

Melastomataceae

Clidemia hirta D.Don

Melastoma malabathricum L.

–

Memecylon ovatum Sm.

Memecylon scutellatum (Lour.) Hook.
and Arn.

–

Meliaceae

Aglaia argentea Blume

–

Azadirachta indica A. Juss.

Chisocheton patens Blume

–

Lansium parasiticum (Osbeck) K.C.Sahni and
Bennet

Menispermaceae

Arcangelisia flava (L.) Merr.

Arcangelisia gusanlung H.S.Lo

Cyclea laxiflora Meirs

Fibraurea tinctoria Lour.

Pericampylus glaucus (Lam.) M.

Moraceae

–

–

Ficus caulocarpa (Miq.) Miq.

Ficus hispida L.f.

Pterolobium densiflorum Prain

–

–

–

Pterospermum acerifolium (L.) Wild.

–

Sterculia sp.

–

–

Memecylon lilacinum Zoll. and Moritzi

Memecylon ovatum Sm.

Memecylon scutellatum (Lour.) Hook.
and Arn.

Pogonanthera pulverulenta (Jack) Blume

–

Aglaia teysmanniana (Miq.) Miq.

–

Chisocheton patens Blume

Chukrasia tabularis A.Juss.

–

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–

Cyclea laxiflora Meirs

–

–

Ficus calcicola Corner

Ficus callophylla Blume

–

Ficus hispida L.f.

Ficus lepicarpa Blume

Ficus punctata Thunb.

–

Ficus schwarzii Koord.

Ficus subulata Blume

–

Ficus tinctoria G. Forst.

Ficus variegata Blume

Muntingiaceae

Muntingia calaburra L.

Myrsinaceae

–

Myrtaceae

Rhodamnia cinerea Jack

–

–

Nyctaginaceae

Bougainvillae glabra Choisy

Olaceae

–

–

Oleaceae

–

Ligustrum confusum Decne.

Oxalidaceae

Averrhoa carambola L.

Pandaceae

Microdesmis casearifolia Planch. ex Hook.

Passifloraceae

Passiflora suberosa L.

Phyllanthaceae

Actephila excelsa (Dalzell) Müll.Arg.

Bridellia tomentosa Blume

Glochidion obscurum (Roxb. ex Willd.) Blume

Ficus lepicarpa Blume

Ficus punctata Thunb.

Ficus sagittata Vahl.

Ficus schwarzii Koord.

Ficus subulata Blume

Ficus sundaica Blume

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–

Ardisia sp.

Rhodamnia cinerea Jack

Syzygium scortechinii (King) P.Chantaranothai
var. *cuneatum* (M.R.Hend.) I.M.Turner

Syzygium stapfianum (King) I.M.Turner

–

Strombosia ceylanica Gardn

Strombosia javanica Blume

Jasminum cordatum Ridl.

Ligustrum confusum Decne.

–

Microdesmis casearifolia Planch. ex Hook.

–

Actephila excelsa (Dalzell) Müll.Arg.

Bridellia tomentosa Blume

Glochidion obscurum (Roxb. ex Willd.) Blume

Glochidion rubrum Blume

–

Phyllanthus erythrocarpus Ridl.

Phyllanthus oxyphyllus Miq.

–

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–

Phytolaccaceae

Rivina humilis L.

Piperaceae

–

Piper aduncum L.

Piper argyrites Ridl. ex C.DC.

–

Piper mucronatum Rich. ex C.DC.

–

Rhamnaceae

–

–

–

Ziziphus sp1

Ziziphus sp2

Rhizophoraceae

–

Rubiaceae

Aidia densiflora (Wall.) Masam.

–

–

Chassalia sp.

Morinda elliptica (Hook.f.) Ridl.

–

–

Ophiorrhiza fruticosa Ridl.

–

Glochidion rubrum Blume

Leptopus australis (Zoll. and Mor.) Pajorkova

–

Phyllanthus oxyphyllus Miq.

Phyllanthus reticulatus Poir.

Sauropus androgynus (L.) Merr.

Sauropus macranthus Hassak.

Rivina humilis L.

Peperomia portulacoides (Lam.) A.Dietr.

–

Piper argyrites Ridl. ex C.DC.

Piper kurzii Ridl.

Piper mucronatum Rich. ex C.DC.

Piper umbellatum L.

Sageratia thea (Osbeck) M.C.Johnst.

Ventilago oblongifolia Blume

Ziziphus pernettyoides Ridl.

–

–

Carallia brachiata (Loir.) Merr.

Aidia densiflora (Wall.) Masam.

Argostemma diversifolium Ridl.

Argostemma inaequilaterum Benn.

Chassalia sp.

–

Mycetia malayana (Wall. ex Ridl.) Craib

Ophiorrhiza discolor R.Br.

Ophiorrhiza fruticosa Ridl.

Ophiorrhiza pallidula Ridl.

Pavetta pauciflora Ridl.

–	<i>Psychotaria lanceolaria</i> Ridl.
–	<i>Psychotaria penangiana</i> Hook.f.
–	<i>Tarenna adangensis</i> (Ridl.) Ridl.
–	<i>Tarenna angustifolia</i> (King) Merr.
<i>Tarenna</i> sp.	<i>Tarenna</i> sp.
Rutaceae	
–	<i>Clausena excavata</i> Burm.f.
<i>Clausena</i> sp.	–
–	<i>Glycosmis chlorosprema</i> (Blume) Spreng
–	<i>Glycosmis trichanthera</i> Guillaumin
<i>Melicope lunu-ankenda</i> T.G.Hartley	–
<i>Paramignya scandens</i> Craib	<i>Paramignya scandens</i> Craib
Salicaceae	
–	<i>Osmelia maingayi</i> King
–	<i>Scolopia spinosa</i> (Roxb.) Warb.
Sapindaceae	
<i>Allophylus cobbe</i> (L.) Raeusch.	<i>Allophylus cobbe</i> (L.) Raeusch.
–	<i>Dimocarpus longan</i> (Lour.) subsp. <i>malesianus</i> Leenh.
Sapotaceae	
<i>Pouteria campechiana</i> (Kunth) Baehni	–
<i>Pouteria obovata</i> (R.Br.) Pierre	<i>Pouteria obovata</i> (R.Br.) Pierre
Solanaceae	
–	<i>Lycianthes biflora</i> (Lour.) Bitter
<i>Physalis minima</i> L.	–
<i>Solanum erianthum</i> D.Don	<i>Solanum erianthum</i> D.Don
Ulmaceae	
–	<i>Celtis philippinensis</i> Blanco
Urticaceae	
–	<i>Debregeasia squamata</i> King ex Hook.f.
–	<i>Debregeasia stimulans</i> (L.f.) Chew
–	<i>Elatostema curtisii</i> (Ridl.) H.Schrot.
–	<i>Elatostema latifolium</i> (Blume) H.Schrot.
–	<i>Elatostema repens</i> (Lour.) Hallier.f.
–	<i>Nothocnide mollissima</i> (Blume) Chew

–	<i>Oreocnide rubescens</i> (Blume) Miq.
<i>Pilea fruticosa</i> Hook.f.	<i>Pilea fruticosa</i> Hook.f.
<i>Pilea trinervia</i> (Roxb.)Wight	–
<i>Pipturus argenteus</i> (G.Forst.) Wedd.	–
<i>Poikilospermum cordifolium</i> (Barg.–Petr.) Merr.	<i>Poikilospermum cordifolium</i> (Barg.–Petr.) Merr.
Violaceae	
<i>Rinorea horneri</i> (Korth.)Kuntze	<i>Rinorea horneri</i> (Korth.) Kuntze
Vitaceae	
<i>Cayratia mollissima</i> (Planch) Gagnep.	–
–	<i>Cayratia wrayi</i> (King) Gagnep.
<i>Cissus hastata</i> Miq.	<i>Cissus hastata</i> Miq.
–	<i>Cissus javanica</i> DC.
<i>Cissus nodosa</i> Blume	<i>Cissus nodosa</i> Blume
<i>Leea indica</i> (Burm.f.) Merr.	<i>Leea indica</i> (Burm.f.) Merr.
–	<i>Leea saxatilis</i> Ridl.
<i>Tetrastigma curtisii</i> (Ridl.) Suess.	–
<i>Tetrastigma leocostaphyllum</i> (Dennst.) Alston	<i>Tetrastigma leocostaphyllum</i> (Dennst.) Alston
<i>Tetrastigma pedunculare</i> (Wall. ex Lawson)	<i>Tetrastigma pedunculare</i> (Wall. ex Lawson)
<i>Tetrastigma scortechinii</i> (King) Gagnep.	<i>Tetrastigma scortechinii</i> (King) Gagnep.

ANGIOSPERMS - MONOCOTYLEDONS

Araceae

<i>Aglaonema cummutatum</i> Schott	–
<i>Alocasia inornata</i> Hallier f.	<i>Alocasia inornata</i> Hallier f.
<i>Alocasia longiloba</i> Miq.	<i>Alocasia longiloba</i> Miq.
<i>Alocasia microrrhizos</i> (L.) G.Don	–
<i>Amophorhallus prainii</i> Hook.f.	–
–	<i>Apoballis mutata</i> (Hook.f.) S.Y. Wong and P.Boyce
<i>Colocasia esculenta</i> (L.) Schott	–
<i>Colocasia gigantea</i> (Blume) Hook.f.	–
<i>Epiprenum aureum</i> (Linden and André) G.S.Bunting	–
<i>Epiprenum giganteum</i> (Roxb.) Schott	–
–	<i>Homalomena griffithii</i> (Schott) Hook.f.

–	<i>Homalomena himilis</i> (Jack) Hook.f.
<i>Philodendron</i> sp.1	–
<i>Philodendron</i> sp.2	–
–	<i>Pothos leptostachyus</i> Schott
<i>Rhaphidophora burkillana</i> Ridl.	<i>Rhaphidophora burkillana</i> Ridl.
<i>Rhaphidophora montana</i> (Blume) Schott	<i>Rhaphidophora montana</i> (Blume) Schott
<i>Rhaphidophora pertusa</i> (Blume) Schott	–
–	<i>Schismatoglottis calyptrata</i> (Roxb.) Zoll. and Moritzi
<i>Scindapsus hederaceus</i> Miq.	<i>Scindapsus hederaceus</i> Miq.
<i>Scindapsus perakensis</i> Hook.f.	<i>Scindapsus perakensis</i> Hook.f.
<i>Syngonium podophyllum</i> Schott	–
–	<i>Typhonium fultum</i> Ridl.
<i>Typhonium</i> sp.	–
Arecaceae	
<i>Areca catechu</i> L.	–
<i>Arenga westerhoutii</i> Griff.	–
–	<i>Calamus manan</i> Miq.
–	<i>Calamus scipionum</i> Lour.
<i>Calamus</i> sp.	–
<i>Caryota mitis</i> Lour.	–
–	<i>Iguanura wallichiana</i> (Wall. ex Martelli) Hook.f.
–	<i>Maxburretia rupicola</i> (Ridl) Furtado
–	<i>Oncospermum horridum</i> (Griff.) Scheff.
<i>Ptychosperma macarthurii</i> (H.Wendel. ex H.J.Veitch) H.Wendl. ex Hook.f.	–
<i>Salacca zalacca</i> (Gaertn.) Voss	–
Asparagaceae	
<i>Cordyline frucicosa</i> (L.) A.Chev.	–
<i>Dracaena angustifolia</i> (Medik.) Roxb.	–
<i>Dracaena maingyai</i> Hook.f.	–
<i>Dracaena porteri</i> Baker	–
–	<i>Dracaena</i> sp.
Commelinaceae	
<i>Tradescantia zebrina</i> Bosse	–

Convallariaceae

Peliosanthes teta Andrews subsp. *humilis*
(Andrews) Jessop ex Gandhi

Peliosanthes teta Andrews subsp. *humilis*
(Andrews) Jessop ex Gandhi

Costaceae

Costus afer Ker Gawl.

–

Dioscoreaceae

Dioscorea bulbifera L.

–

Dioscorea glabra Roxb.

–

Dioscorea hispida Dennst.

–

Maranthaceae

Calathea lutea (Aubl.) E..Mey. ex Schult.

–

Musaceae

Musa acuminata

–

Orchidaceae

–

Adenancos parviflora Ridl.

–

Adenancos sumatrana J.J.Sm

–

Appendicula anceps Blume

–

Bulbophyllum flammulferum Ridl.

–

Calanthe ceciliae Reichb.f.

–

Calanthe vestita Lindl.

–

Corybas calcicolus J.Dransf. and G.Smith

Corymborkis veratrifolia Blume

Corymborkis veratrifolia Blume

–

Dendrobium subulatum (Blume) Lindl.

–

Goodyera pusilla Blume

–

Grosourdyia appendicula (Blume) Reicheb.f.

–

Oberonia sinuosa Ridl.

–

Pennilabium angraecum (Ridl) J.J.Sm.

–

Pholidota imbricata Hook.

–

Phreatia plantaginifolia (K.D.Koenig)
Ormerod

–

Polystachya concreta (Jacq.) Garay and
H.R.Sweet

–

Pomatocalpa andamanica (Hook.f.) J.J.Sm.

–

Renantherella histriconica (Reichb.f.) Ridl.

–

Schoenorchis micrantha Blume

Spathoglottis plicata Blume

–

- *Taeniophyllum filiforme* J.J.Sm.
- *Thelasis pygmaea* Blume
- *Trichoglottis retusa* Blume
- *Ventricularia tenuicaulis* (Hook.f.) Garay

Pandanaceae

Pandanus penangensis Ridl. *Pandanus penangensis* Ridl.

Poaceae

- Bambusa* sp. –
- *Dichanthium mucronulatum* R.K.Jansen
- *Echinochloa colona* (L.) Link
- *Eleusine indica* (L.) Gaertn.
- Eragrostis pilosa* (L.) P.Beauv. *Eragrostis pilosa* (L.) P.Beauv.
- *Eragrostiis amobilis* (L.) Wight and Arn, ex Hook.
- *Oplismenus compositus* (L.) P.Beauv.
- *Sporobulus indicus* (L.) R.Br. var. *flaccidus* (Roem. and Schult.) Veldkamp

Smilacaceae

- Smilax leucophylla* Blume –
- Smilax* sp. –

Zingiberaceae

- *Alpinia javanica* Blume
- Amomum testaceum* Ridl. *Amomum testaceum* Ridl.
- Etilingera littoralis* (J.Koenig) Giseke *Etilingera littoralis* (J.Koenig) Giseke
- Hornstedtia conica* Ridl. –

TOTAL:
Number of species = 200
Number of family = 71

TOTAL:
Number of species = 262
Number of family = 70

Table 2. Families not recorded from the burned area and the checklist of Kiew (2014) .

Absent in the burned area	Absent from Kiew's checklist
FERNS	
Lomariopsidaceae	Davaliaceae
Schizeaceae	Lygodiaceae
SPERMATOPHYTES	
DICOTYLEDONS	
Balsaminaceae	Amaranthaceae
Begoniaceae	Caricaceae (*planted)
Boraginaceae	Compositae
Capparaceae	Icacinaceae
Clusiaceae	Nyctaginaceae (*planted)
Convovulaceae	Oxalidaceae (*planted)
Elaeocarpaceae	Passifloraceae
Myrsinaceae	
Olaceae	
Rhizophoraceae	
Salicaceae	
Ulmaceae	
MONOCOTYLEDONS	
	Commelinaceae
	Costaceae (*planted)
	Dioscoriaceae
	Maranthaceae (*planted)
	Musaceae
	Smilacaceae

DISCUSSION

The greater species number in the 2014 checklist can be attributed to the much larger study area explored by many researchers over a period of more than a hundred years. Despite disparities in methods of data collection, the differences in species composition between the two checklists can be attributed to changes in the forest environment. For example, the reduction of forest cover may explain the appearance of *Davallia denticulata*, and heliophilic species of Commelinaceae, Dioscoridaceae and Smilacaceae that usually grow in open environments and the absence of species of Begoniaceae, Lomariopsidaceae, and Schizeaceae that prefer shaded and more humid environments.

The forest fire created spatial patterns of vegetation of contrasting plant diversity. One formation is dominated by *Macaranga tanarius*; the other by *Pterolobium densiflorum*. The dominance of *Pterolobium densiflorum* is the result of vegetative regrowth from the base of the plant that was not destroyed by the fire, whereas *Macaranga tanarius* dominance is the result of seed dispersal.

Pterolobium densiflorum is a robust creeper. Its stem is furnished with thorns and form piles with layers that act like a sieve and prevent seeds from reaching the soil except those that are tiny and have a smooth surface such as *Clausaena* sp. In contrast, the erect *Macaranga tanarius* tree formation offer a better chance for seeds to reach the soil.

Within the *Macaranga tanarius* formation there are spots where tall *Carica papaya* averaging above 10 m in height are abundant. According to Kiew (pers. comm.) both *Carica papaya* and *M. tanarius* already occupied the burned area a year after the incident. It indicates that the two plants were the pioneer species and the *Carica papaya* trees are taller probably because they grow faster than the *M. tanarius*. Early colonisation by these two plants was probably facilitated by seed dissemination by frugivorous birds. During the survey, open fruits of *M. tanarius* were scattered on the forest floor. Likewise, birds resting on *M. tanarius* and consuming seed were a common sight in the forest. On the other hand, papaya was observed as a preferred fruit tree in gardens around Batu Caves where its fruits are eaten by birds and so dispersed the seed to the burned area. Under full sun, papaya seeds exhibit a high rate of germination within three days. Openings created by fire not only facilitated early colonisation by *Carica papaya* and *M. tanarius* but also by the co-dominant *Muntingia calabura*. They created a shaded understory where young plants of non-pioneer species can become established suggesting their importance in the process of vegetation recovery. Neither of these pioneer species were noted in the previous checklist.

Arenga westerhoutii, *Spathodea campanulatum* and *Pentace triptera* were mature trees within the burned area where they occurred in scattered spots. *Spathodea campanulatum* and *Pentace triptera* were found within the forest entrance near Nyamuk Wall, whereas *Arenga westerhoutii* occurred on slightly higher elevated areas. The fire incident started at 10 a.m. and was under control at 3 p.m., but continued to smolder for a further three days. It affected an area of about 17 ha in an elevation range of 60 to 250 m. The survival of these trees suggests the existence of a zone of milder intensity of fire or its rapid movement or a combination of both. During the fire incident, weather was reported to be unusually windy (Tan 2016) that was the major cause for the fire spreading and consuming such a large area. The occurrence of clumps of *Arenga westerhoutii* suggests the possible adaptation of this palm to fire. *Arenga westerhoutii* has seeds similar to *Arenga pinnata*, in which the rupture of the extremely hard seed coat is assisted by short exposure to high temperatures during the burning (Chairun 1994). This thermal scarification by fire favours the growth of seedlings in the cleared space.

Podocarpus nerifolius was found on higher elevations where the fire incident ended. Their size of about 10 cm dbh as well as the presence of burn marks on their thick bark contrasted with the smaller, unmarked trees of other species surrounding them. This pattern concurs with report of Chin (1977) on the survival of *Podocarpus polystachyus* after the fire incident on Gua Musang. It supports the hypothesis that the thicker bark of these *Podocarpus* species conferred increased resistance to fire.

CONCLUSION

Three years after the forest fire, the affected area is well covered by both pioneer and non-pioneer plants. However, this promising recovery should not be interpreted as resilience of Batu Caves ecosystem to repeated major disturbances. Indeed, considerable spatial variations of plant succession and vegetation recovery could be observed within the burned area. It remains unclear if these were generated by different fire intensities or if they can be linked to various regeneration capacities of pre-existing vegetation zones. As precaution and in a context of increasingly isolated and threatened floras, all possible measures need to be taken to avoid similar fire incidents.

The bare land resulting from fire incident provided a precious opportunity to observe vegetation succession and possible niche differentiations. We suggest that further surveys should be carried out at regular time intervals to determine how limestone hill flora may recover in the long term from incidents of forest fire. In order to extend this study, we propose that future floral surveys at Batu Caves should include observations along the same path. A similar approach permitted Aliaa-Athirah *et al.* (2019) to demonstrate a local recovery process in Gua Musang through a steady increase of floral diversity over a hundred years.

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