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PRELIMINARY CHECKLIST OF BEETLES ASSEMBLAGES (ORDER: COLEOPTERA) FROM LIMESTONE FORESTS IN SOUTHERN SARAWAK, MALAYSIA

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ABSTRACT

Beetles are becoming important subjects of ecological interest for conservation studies due to their high biodiversity and distribution, despite rapid urbanisation and deforestation activities. This study initiates to present a preliminary checklist of beetles from limestone forests in Southern Sarawak, Malaysia which included four selected localities within Bau and Padawan districts, namely, Mount Serumbu (Bau), Fairy Cave Nature Reserve (Bau), Raya Cave (Padawan) and Temurang Cave (Padawan). Each sampling trip was conducted for five consecutive days, using both active and passive methods. As a result, a total of 786 individuals representing 191 species (56 confirmed species and 135 morphospecies) from 81 genera under 57 subfamilies and 23 families were successfully recorded. Overall, the most speciose family was represented by Carabidae (39 species; 20.42%), followed by Scarabaeidae (32 species; 16.75%), Chrysomelidae (29 species; 15.18%), and Tenebrionidae (22 species; 11.52%), respectively. Meanwhile, Carabidae was the most abundant family (175 individuals; 22.26%), followed by Scarabaeidae (126 individuals; 16.03%), Chrysomelidae (124 individuals; 15.78%), and Tenebrionidae (116 individuals; 16.03%), respectively. In general, *Triplatoma macleayi* (Erotylidae) was the most abundant species with a total of 56 individuals (7.12%), followed by *Amarygus* sp. 1 (Tenebrionidae) with 39 individuals (4.96%). To conclude, this study is hopefully beneficial to document the diversity and abundance of beetles within limestone areas and useful to the local authority in identifying potential hotspot area(s) for biodiversity conservation and effective management practice. However, it is recommended that future studies should include other limestone forests, covering areas in the central and northern regions of Sarawak.

Keywords: Species assemblages, diversity, coleopterans, cave, insect

ABSTRAK

Kumbang menjadi subjek berkepentingan ekologi terutamanya dalam kajian pemuliharaan kerana kepelbagaian biologi dan taburannya yang tinggi, walaupun dikelilingi oleh kegiatan pembandaran dan penebangan hutan. Kajian ini membentangkan senarai semak awal kumbang dari hutan batu kapur di Sarawak Selatan, Malaysia yang merangkumi empat kawasan dalam daerah Bau dan Padawan, iaitu Gunung Serumbu (Bau), Rizab Semulajadi Gua Pari-Pari (Bau), Gua Raya (Padawan) dan Gua Temurang (Padawan). Setiap aktiviti persampelan dijalankan selama lima hari berturut-turut, menggunakan kedua-dua kaedah aktif dan pasif. Hasilnya, sebanyak 786 individu mewakili 191 spesies (56 spesies ditentu-sah dan 135 spesies morfo) daripada 57 subfamili dan 23 famili berjaya direkodkan. Secara keseluruhan, famili dengan spesies yang paling banyak diwakili oleh Carabidae (39 spesies; 20.42%), diikuti oleh Scarabaeidae (32 spesies; 16.75%), Chrysomelidae (29 spesies; 15.18%) dan Tenebrionidae (22 spesies; 11.52%). Di samping itu, Carabidae merupakan famili paling dominan (175 individu; 22.26%), diikuti oleh Scarabaeidae (126 individu; 16.03%), Chrysomelidae (124 individu; 15.78%) dan Tenebrionidae (116 individu; 16.03%). Secara umumnya, *Triplatoma macleayi* (Erotylidae) merupakan spesies yang paling banyak direkodkan dengan 56 individu (7.12%), diikuti oleh *Amarygus* sp.1 (Tenebrionidae) dengan 39 individu (4.96%). Kesimpulannya, kajian ini diharap dapat menyumbang kepada dokumentasi kepelbagaian dan kelimpahan kumbang di kawasan batu kapur dan berguna kepada pihak berkuasa tempatan dalam mengenalpasti kawasan khas yang berpotensi untuk pemuliharaan kepelbagaian biologi dan amalan pengurusan yang efektif. Adalah dicadangkan agar kajian pada masa hadapan turut merangkumi kawasan hutan batu kapur di kawasan tengah dan utara Sarawak.

Kata kunci: Himpunan spesies, kepelbagaian, kumbang, gua, serangga

INTRODUCTION

Over-exploitation and deforestation due to globalisation were never a fresh topic within the fast-phasing world. Species checklists were increasing the efficiency and benefits of biodiversity conservation activities to overcome the consequences of over-exploitation. With species checklists, an inventory of species from certain localities within certain durations can be determined along with localities' environmental conditions including several factors like type of vegetation, temperature, soil pH value, humidity, air movement and light intensity. These factors might affect the biodiversity there and the latest species checklist. Therefore, a species checklist is important for biologists and managers to decide on biodiversity conservation action steps (Biodiversity Philippines 2022). According to Chargualaf and Salas (2022), a limestone forest is a forest consisting of limestone with the presence of flora and fauna with shallow and neutral to mildly alkaline soil surface. According to World Wildlife Fund Malaysia (2018), there was an estimated 26,000 ha of forested limestone areas mostly concentrated in northern Peninsular Malaysia, whereas in Sabah and Sarawak, the limestone forests were around 50,000 ha.

Beetles from the order Coleoptera (Class: Insecta) were estimated to be around 400,000 species, representing two-fifths of all insect species and one-fourths of all known animal life forms worldwide, while new species are still being discovered to date (Bouchard et al. 2017). Beetles are winged insects which have a complete metamorphosis process. According to Sane (2003), insect wings were one of the main contributors to their evolutionary success, helping them to evade predators, food seeking and colonisation of new habitats. Elytra, which are hardened wing-cases originating from their forewings are distinguishing beetles from other insect orders and are believed to be one of the most essential and central to the evolutionary successes in them (Linz et al. 2016). The main function of elytra is to protect the vulnerable membranous hind wings and the abdomen from environmental stressors and predators (Hammond 1979).

Many important roles from an ecological and economic point of view around the globe were played by the coleopterans, such as pollinators, decomposers, biological and environmental indicators, biological control agents, and agricultural pests (Chung 2007; da Rocha et al. 2010). As suggested by Shahabuddin and Hasanah (2014), the changes in environment or habitat condition can be detected by coleopterans as bioindicators which allow assessment of the impacts of anthropogenic activities on the biota without examining the whole biota. Besides, Harper and Hawksworth (1994) reported that qualitative and quantitative measures of biodiversity that provide a basis for decision-making in relation to conservation can be presented through information on beetle assemblages. On the other hand, some beetles are harmful to both the ecosystem and human society for being agricultural pests which significantly cause massive damage to plantations and reduce crop yields.

In this study, the documentation on species assemblages of beetles from limestone forests in Southern Sarawak, Malaysia is of interest, since most ecological studies were reporting animals' diversity from major forest types such as mixed dipterocarp, mangrove, and peat swamp forests. Thus, a pilot study should be initiated to document species accounts of beetles from limestone forests in southern Sarawak, which could also potentially lead to discoveries of endemic or cryptic beetle species.

MATERIALS AND METHODS

Study Sites

Four localities which were covered by limestone forest were selected for this study as in Figure 1, namely, Fairy Cave, Bau (1.2239° N, 110. 0711°E), Raya Cave, Padawan (1.2363° N, 110.4304° E), Mount Serumbu, Bau (1.4254° N, 110.2232° E) and Temurang Cave, Padawan (1.2087° N, 110.2709° E), where each site was sampled for five consecutive nights. While all four sites are considered limestone forests, notable differences were seen due to anthropogenic activities by the local communities. Fairy Cave's surroundings are home to several rare palm species, including *Arenga pinnata*, *A. undulatifolia*, and *Calamus ornatus* (Sarawak Forestry n.d.). In contrast, Temurang Cave is covered by lush tropical forests (Amazing Padawan 2017), pepper farms, and orchards. Whereas Mount Serumbu exhibits an open vegetation condition resulting from anthropogenic activities, with an abundance of durian trees, langsat trees, *Arenga* palms, and bamboo replacing the once mixed dipterocarp and heath forests (Abuseman 2012). Lastly, Raya Cave is situated in Chupak Village, surrounded by paddy fields (Bombastic Borneo 2021).

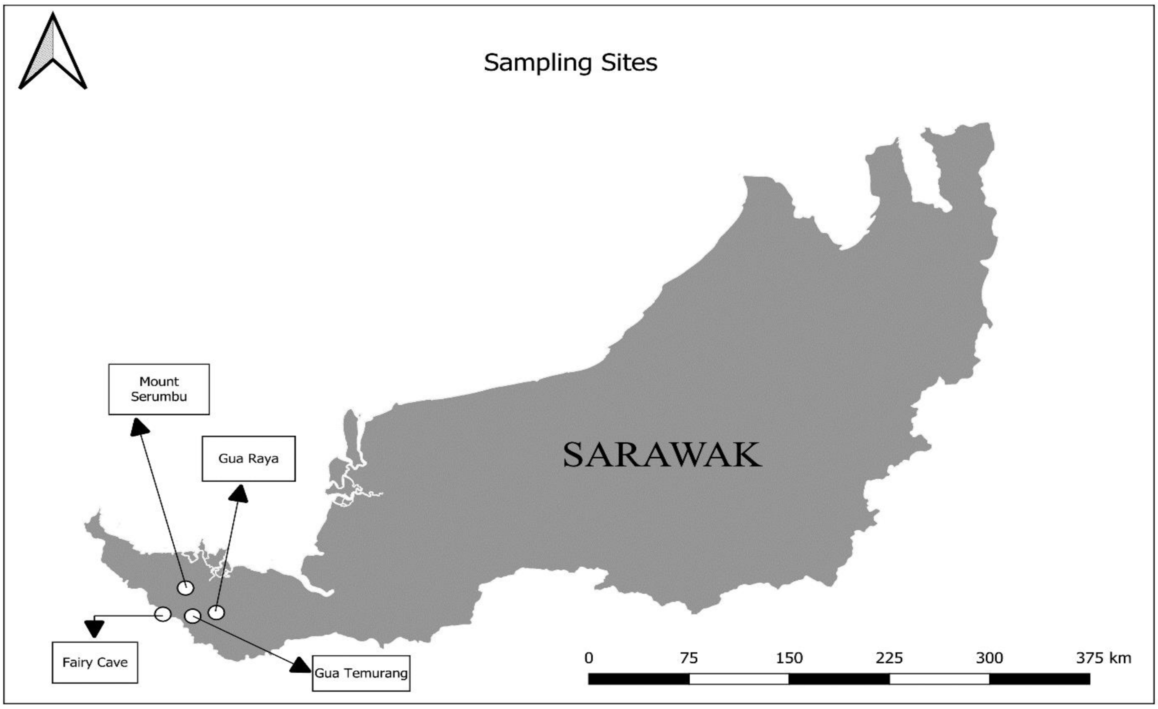

Figure 1. Location of study sites of limestone forests in Southern Sarawak

Sampling of Coleopterans

Both passive and active methods were used in this study. For active sampling, hand-picking was done twice a day with the aid of an aerial net. The active method was conducted for one to two hours every morning (7:30 a.m.) and evening (6:30 p.m.) along the trails. Hand picking was conducted to collect harmless and threatless medium to large-sized coleopterans. Targeted coleopterans were held on the sides of thorax parts to keep their mandibles away from the skin. Meanwhile, those with spines or spikes were handled using the aerial net (Texas & Agrilife 2022). As for the passive method, two modified Pennsylvanian light traps (MPLTs), 10 flight intercept traps and 10 baited traps were deployed randomly along the trails. MPLTs were set up every evening from 6:00 pm until the next morning at 6:00 am, targeted nocturnal and light-attracted beetles, which were collected every morning. For both flight intercept traps, and baited traps, artificial baits that consist mixtures of yeast, honey, beer, and molasses and rotten fruits such as pineapples and papayas were added to attract the beetles and the samples were collected every two to three days. All samples were then sorted and labelled accordingly, of which some samples were preserved in absolute ethanol, and some were pinned following appropriate procedures.

Species Identification

For identification, all adult coleopterans were sorted accordingly into family, subfamily and/or species level where possible following descriptions by Chung (2003), Hill and Abang (2010) and Bosuang et al. (2017), as well as with comparisons made with voucher specimens deposited at UNIMAS Insect Reference Collection, and also Research, Development, and Innovation Division (SFC). As identification keys and available sources are very limited, some samples were identified as morpho species and classified under the sub-familial level.

Data Analysis
The number of individuals with respective species lists including the number of families and subfamilies, were recorded in appropriate data sheets. The relative abundance for each species and morpho species was calculated using Microsoft Excel and presented in percentages. The number of individuals and the number of species for each beetle family were also visualised in histograms respectively.

RESULTS AND DISCUSSION

This first comprehensive beetle checklist from limestone forests in Southern Sarawak has recorded a total of 786 individuals representing 191 beetle species (56 confirmed species and 135 morpho species) under 81 confirmed genera from 57 subfamilies and 23 families (Table 1). Carabidae (ground beetles) was the most diverse family with 39 species (20.42%), followed by Scarabaeidae (scarab beetles) with 32 species (16.75%), Chrysomelidae (leaf beetles) with 29 species (15.18%), and Tenebrionidae (darkling beetles) with 22 species (11.52%), respectively (Figure 2). Carabidae was also the most abundant family represented by 175 individuals (22.26%), followed by Scarabaeidae with 126 individuals (16.03%), Chrysomelidae with 124 individuals (15.78%) and Tenebrionidae with 116 individuals (14.76%), respectively (Figure 3). The Simpson 1-D and Shannon H indices for all localities were: Mount Serumbu (0.9173; 3.35), Raya Cave (0.9428; 3.814), Temurang Cave (0.9722; 4.094) and Fairy Cave (0.9687; 3.91) respectively of which suggested that all four sites showed a considerably high diversity of beetles. There were numerous studies on the diversity and abundance of beetles conducted within Malaysia, such as Musthafa et al. (2019) and Zakaria et al. (2022) in Peninsular Malaysia, as well as Abin et al. (2021) and Japir et al. (2021) in Sabah. Overall, the alpha diversity indices from all four sites were comparable to these studies, indicating the high diversity of beetles in southern Sarawak.

Limestone forests are known for their rich flora and fauna diversity and high levels of endemism, earning them the reputation of being the “arks of biodiversity” (Clements et al. 2006). For instance, Fairy Cave is home to a variety of bat species, including the dusky fruit bats and insectivorous bats from the families Hipposideridae and Rhinolophidae, some of which include beetles in their diet (Feng 2006; Hall et al. 2011). However, these unique ecosystems are more susceptible to disturbances when compared to other forest types. This vulnerability can be attributed to the high concentrations of calcium and magnesium in limestone soils, which differ from the mineral composition found in other soils. These distinctive soil characteristics have a great impact on the local vegetation, contributing to its unique appearance and species composition (Ngo & Nguyen 2019). Interestingly, *Neptosternus sarawakensis*, a species that has previously only been recorded in Sarawak was obtained in this study (Hendrich & Balke 2003). However, establishing its endemism status requires further studies through sufficient distribution of data.

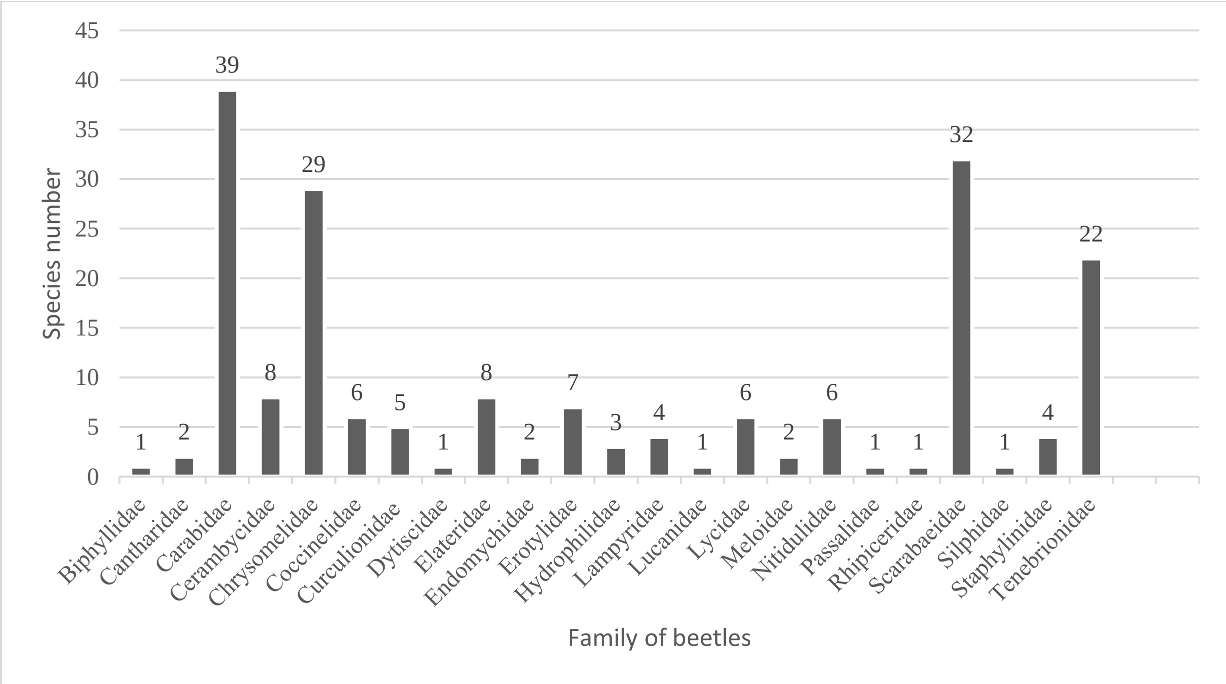

Figure 2. No. of beetle species per family recorded from limestone forests in Southern Sarawak

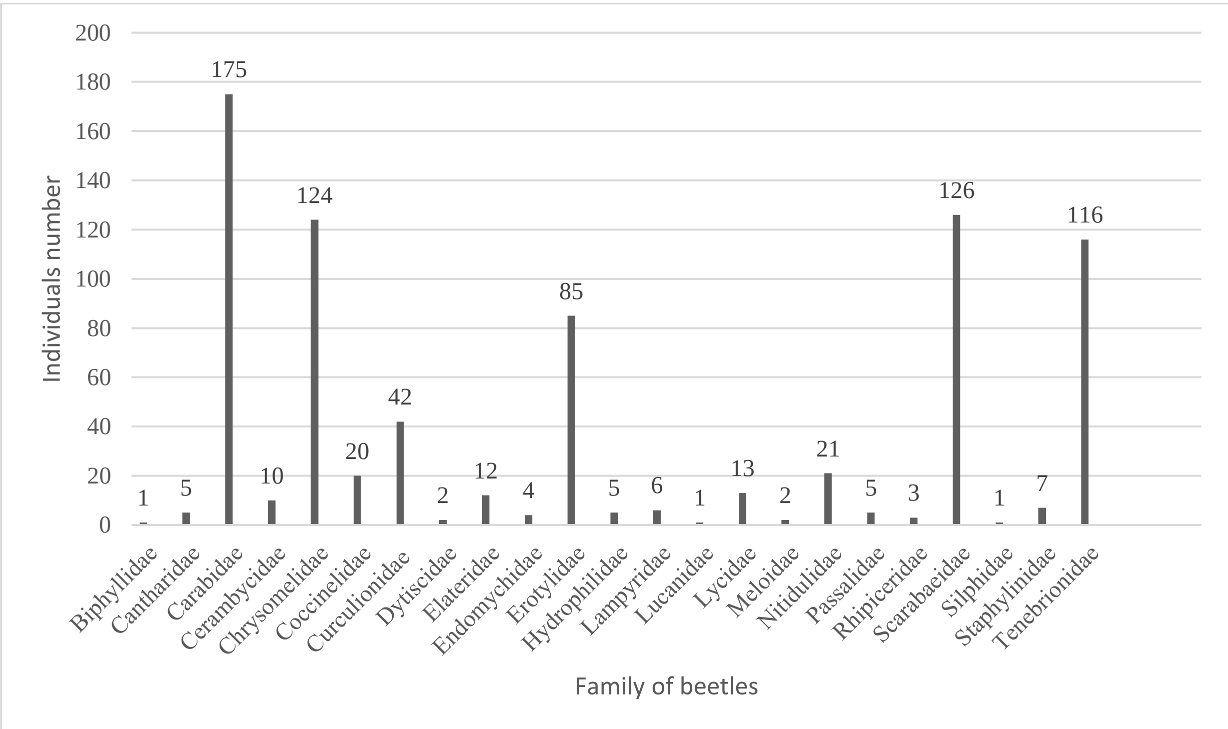

Figure 3. No. of individuals per family Southern Sarawak

Table 1. Preliminary checklist of beetles from limestone forests in Southern Sarawak

Family / Subfamily (No. of subfamilies)	**(No. of Species)**	**No. of individuals (Total individuals in the respective family)**	**Relative abundance according to species (%)**
Biphyllidae (1)	(1)	(1)	
Biphyllinae	*Biphyllinae sp.1	1	0.13
Cantharidae (1)	(2)	(5)	
Cantharinae	*Cantharinae sp.1	4	0.51
	*Cantharinae sp.2	1	0.13
Carabidae (7)	(39)	(175)	
Brachininae	*Pheropsophus javanus*	1	0.13
Carabinae	*Carabinae sp.1	11	1.40
	*Carabinae sp.2	3	0.38
	*Carabinae sp.3	22	2.80
	*Carabinae sp.4	13	1.65
	*Carabinae sp.5	10	1.27
	*Carabinae sp.6	12	1.53
	*Carabinae sp.7	3	0.38
	*Carabinae sp.8	2	0.25
	*Carabinae sp.9	2	0.25
	*Carabinae sp.10	1	0.13
	*Carabinae sp.11	1	0.13
	*Carabinae sp.12	3	0.38
	*Carabinae sp.13	2	0.25
Cicindelinae	*Abroscelis tenuipes tenuipes*	4	0.51
	Cosmodela aurulenta	7	0.89
	Cylindera filigera	1	0.13
	Cylindera sp.1	1	0.13
	Pericalus sp.1	1	0.13
Harpalinae	*Catascopus* sp.1	1	0.13
	Chlaenius sp.1	2	0.25
	Dicranoncus femoralis	1	0.13
	*Harpalinae sp.1	1	0.13
	Lebia sp.1	36	4.58
	Lebia sp.2	2	0.25
	Mochtherus sp.1	2	0.25
	Orthogonius sp.1	1	0.13
	Orthogonius sarawakensis	4	0.51
	Poecilus sp.1	2	0.25
	Pterosthicus sp.1	1	0.13
	Pterosthicus cursor	1	0.13
	Pterostichus melanarius	1	0.13
Lebiinae	*Allocota viridipennis*	7	0.89
	*Lebiinae sp.1	1	0.13
	*Lebiinae sp.2	1	0.13
Paussinae	*Pseudozaena orientalis*	8	1.02
	*Paussinae sp.1	1	0.13
	*Paussinae sp.2	1	0.13

Panagaeinae	*Craspedophorus* sp.1	1	0.13
Cerambycidae (3)	(8)	(10)	
Lamiinae	*Batocero* sp.1	1	0.13
	Acalolepta rusticatrix	1	0.13
	*Lamiinae sp.1	1	0.13
	*Lamiinae sp.2	1	0.13
Cerambycinae	*Cerambycinae sp.1	2	0.25
	*Cerambycinae sp.2	2	0.25
	*Cerambycinae sp.3	1	0.13
Parandrinae	*Komiyandra* sp.1	1	0.13
Chrysomelidae (6)	(29)	(124)	
Cassidinae	*Aspidimorpha miliaris*	4	0.51
	Basiprionota decemmaculata	1	0.13
	Cassida catenate	1	0.13
	Cassida cf. cricumdata	2	0.25
	*Cassidinae sp.1	6	0.76
	*Cassidinae sp.2	1	0.13
Alticinae	*Alticinae sp.1	1	0.13
Galerucinae	*Aplosonyx albicornis*	1	0.13
	Aulacophora indica	16	2.04
	Aulacophora postica	18	2.29
	Aulacophora sp. 1	3	0.38
	Aulacophora sp.2	2	0.25
	Aulacophora sp.3	3	0.38
	Aulacophora sp.4	2	0.25
	*Galerucinae sp.1	1	0.13
	Haplosaenidea variabilis	6	0.76
	Hoplosaenidae sp.1	1	0.13
	Metrioidea grandis	7	0.89
	Monolepta sp. 1	2	0.25
	Monolepta sp.2	14	1.78
	Strobiderus sp.1	1	0.13
Eumolpinae	*Eumolpinae sp.1	1	0.13
	Plagiodera sp.1	1	0.13
Crocerinae	*Lema lacertosa*	1	0.13
Chrysomelinae	*Chrysomelinae sp.1	12	1.53
	*Chrysomelinae sp.2	8	1.02
	*Chrysomelinae sp.3	4	0.51
	*Chrysomelinae sp.4	3	0.38
	*Chrysomelinae sp.5	1	0.13
Coccinelidae (2)	(6)	(20)	
Coccinelinae	*Adalia decampunctata*	2	0.25
	*Coccinelinae sp.1	4	0.51
	*Coccinelinae sp.2	1	0.13
Epilachninae	*Epilachninae sp.1	4	0.51
	*Epilachninae sp.2	1	0.13
	Epilachna indica	8	1.02
Curculionidae (4)	(5)	(42)	

Cryptorhynchinae	*Cryptorhynchinae sp.1	2	0.25
Curculioninae	*Curculioninae sp.1	4	0.51
Dryophthorinae	*Rhynchophorus vulneratus*	27	3.44
	Rhodobaenus sp.1	2	0.25
Scolytinae	*Scolytinae sp.1	7	0.89
Dytiscidae (1)	(1)	(2)	
Laccophilinae	*Neptosternus sarawakensis*	2	0.25
Elateridae (4)	(8)	(12)	
Agrypninae	*Alaolacon* sp.1	2	0.25
	Compsolacon borneoensis	1	0.13
	Cryptaulus sp.1	1	0.13
Athoinae	*Anthoinae sp.1	2	0.25
	Athous sp.1	1	0.13
Elaterinae	*Anchastus bicolor*	2	0.25
	*Elaterinae sp.1	1	0.13
Melanotinae	*Melanotinae sp.1	2	0.25
Endomychidae (2)	(2)	(4)	
Endomychinae	*Endomychinae sp.1	3	0.38
Lycoperdininae	*Eumorphus westwoodi*	1	0.13
Erotylidae (1)	(7)	(85)	
Erotylinae	*Acropteroxys* sp.1	1	0.13
	Amblyopus sp.1	1	0.13
	Encaustes sp.1	1	0.13
	Encaustes sp.2	3	0.38
	Encaustes sp.3	20	2.54
	Languria mozardi	3	0.38
	Triplatoma macleayi	56	7.12
Hydrophilidae (2)	(3)	(5)	
Acidocerinae	*Chasmogenus abnormalis*	1	0.13
	Chasmogenus anomalla	2	0.25
Hydrophilinae	*Hydrophilinae sp.1	2	0.25
Lampyridae (2)	(4)	(6)	
Lampyrinae	*Lampyrinae sp.1	1	0.13
	*Lampyrinae sp.2	1	0.13
	*Lampyrinae sp.3	1	0.13
Luciolinae	*Pteroptyx* sp.1	3	0.38
Lucanidae (1)	(1)	(1)	
Lucaninae	*Lucaninae sp.1	1	0.13
Lycidae (4)	(6)	(13)	
Lycinae	*Cautires obsoletus*	4	0.51
	*Lycinae sp.1	1	0.13
Lyropaeinae	*Platerodrilus foliaceus*	3	0.38
Metriorrhynchinae	*Metriorrhynchus* sp. 1	1	0.13
Platerodinae	*Plateros* sp.1	2	0.25
	Plateros sp.2	2	0.25

Meloidae (1)	(2)	(2)	
Meloinae	*Meloidae sp.1	1	0.13
	*Meloidae sp.2	1	0.13
Nitidulidae (1)	(6)	(21)	
Nitidulinae	*Nitidulidae sp.1	10	1.27
	*Nitidulidae sp.2	1	0.13
	*Nitidulidae sp.3	1	0.13
	*Nitidulidae sp.4	1	0.13
	*Nitidulidae sp.5	3	0.38
	Stelidota multiguttata	5	0.64
Passalidae (1)	(1)	(5)	
Passalinae	*Aceraius wallacei*	5	0.64
Rhipiceridae (1)	(1)	(3)	
Sandalinae	*Sandalus* sp.1	3	0.38
Scarabaeidae (5)	(32)	(126)	
Cetoniinae	*Agestrata belitungana*	1	0.13
	*Cetoiinae sp.1	3	0.38
	*Cetoiinae sp.2	1	0.13
	*Cetoiinae sp.3	5	0.64
	Ixorida regis sumantra	2	0.25
Dynastinae	*Chalcosoma atlas*	5	0.64
	Xylotrupes gideon borneensis	1	0.13
Melolonthinae	*Apogonia* sp.1	2	0.25
	Apogonia expeditionis	2	0.25
	Apogonia destructor	17	2.16
	Apogonia waterstradti	1	0.13
	Holotrichia serrata	23	2.93
	Leucopholis staudingeri	2	0.25
	Maladera sp.1	3	0.38
	Maladera sp.2	2	0.25
	Maladera sp.3	1	0.13
	Schoenherria hispida	2	0.25
Rutelinae	*Adoretus compressus*	5	0.64
	Anomala ptenomeloides	7	0.89
	Anomala sp.1	1	0.13
	Mimela sp.1	2	0.25
	Mimela sp.2	1	0.13
	Mimela maculicollis	1	0.13
	Parastasia sp.1	2	0.25
	*Rutelinae sp.1	18	2.29
Scarabaeinae	*Onthophagus semiaureus*	2	0.25
	Onthophagus sp 1	3	0.38
	Onthophagus sp.2	2	0.25

	*Scarabaeinae sp.1	2	0.25
	*Scarabaeinae sp.2	3	0.38
	*Scarabaeinae sp.3	2	0.25
	*Scarabaeinae sp.4	2	0.25
Scolytidae (1)	(1)	(7)	
Scolytinae	*Scolytinae sp.1	7	0.89
Silphidae (1)	(1)	(1)	
Silphinae	*Diamesus osculans*	1	0.13
Staphylinidae (1)	(4)	(7)	
Staphylininae	*Staphylininae sp.1	4	0.51
	*Staphylininae sp.2	1	0.13
	*Staphylininae sp.3	1	0.13
	*Staphylininae sp.4	1	0.13
Tenebrionidae (5)	(22)	(116)	
Diaperinae	*Neomida* sp.1	2	0.25
	Rhophobas asperatus	1	0.13
Blaptinae	*Gonocephalum* sp.1	2	0.25
Lagriinae	*Lagriinae sp.1	4	0.51
Stenochiinae	*Derosphaerus borneensis*	2	0.25
	Strongylium sp.1	5	0.64
	Strongylium sp.2	1	0.13
	Strongylium insigne	1	0.13
	*Stenochiinae sp.1	1	0.13
Tenebrioninae	*Amarygmus* sp.1	39	4.96
	Amarygmus sp.2	21	2.67
	Amarygmus concolor	13	1.65
	Bradymerus sp.1	1	0.13
	Rhophobas asperatus	3	0.38
	*Tenebrioninae sp.1	3	0.38
	*Tenebrioninae sp.2	3	0.38
	*Tenebrioninae sp.3	4	0.51
	*Tenebrioninae sp.4	2	0.25
	*Tenebrioninae sp.5	3	0.38
	*Tenebrioninae sp.6	2	0.25
	*Tenebrioninae sp.7	1	0.13
	*Tenebrioninae sp.8	2	0.25
23/ (57)	(191)	786	100.00

*****morpho species

The total individuals collected respectively from all localities were 244 individuals from Mount Serumbu, 146 from Raya Cave, Serian, 256 from Temurang Cave, Padawan and 140 from Fairy Cave. Most individuals were collected from Temurang Cave, out of all localities with 86 species (22 confirmed species and 64 morpho species) representing 16 families and 33 subfamilies. This was followed by Mount Serumbu with a total of 64 species recorded (26 confirmed species and 38 morpho species) under 28 subfamilies under 15 families. Sixty six species (12 confirmed species and 54 morpho species) and 61 species (17 confirmed species and 44 morpho species) were recorded from Raya Cave and Fairy Cave, respectively. Among the confirmed species, *Apogonia destructor* and *Holotrichia serrata* were recorded from all four localities which may be the common species among these places. Besides common species, some species might be found as unique from certain localities. For example, *Triplatoma macleayi* was only collected from Mount Serumbu with 56 individuals, and 16 individuals of *Aulacophora indica* were only collected from Temurang Cave, Padawan. *Apogonia destructor* and *H. serrata* both belong to the Melolonthinae subfamily under the Scarabaeidae family. Melolonthinae was well known for their phytophagous behaviour in both adult and grub stages. Most adults are leaf-feeding insects while grubs were a serious pest for some crops and grasslands as they fed on roots of grasses, clovers, and organic matter in the soil (Adam & John 2019). Which might make this subfamily more common to all types of vegetation.

The usage of the modified Pennsylvanian light traps (MPLTs) yielded a significantly higher number of captures, as most beetle families, including Carabidae, Tenebrionidae, and Scarabaeidae, exhibit phototrophic behaviour (Dahmar & Khadakkar 2014; Kádár & Szél 1989). Moreover, MPLTs addressed the limitations of pitfall traps, which may result in incomplete beetle checklists in specific environments (Ulyshen et al. 2005), by enhancing the efficiency of collecting 'trap-shy' and 'non-runner' Carabidae species (Benest 1989; Jocque et al. 2016). Conversely, flight-intercept traps and baited traps have proven effective for capturing saproxylic beetles, such as Staphylinidae, Scarabaeidae, and Scritidae (Janssen et al. 2009). Certain anthophagous beetle families including Nitidulidae, are attracted to decaying fruits placed within baited traps (Mutinelli et al. 2015).

Scarabaeidae are involved in many ecological roles such as pollinators, decomposers and agriculture pests making them easier to encounter during samplings, due to their wide range of feeding diets including dungs, fruits, flowers, leaves, carrion, and many others (Kirmse & Ratcliffe 2019). Their nocturnal and positive phototaxis behaviours might be the reason why they are attracted towards MPLTs. In a similar study on beetles' diversity, Marcellinus et al. (2022) managed to document 64 individuals of eight scarab beetles as the most diverse and abundant family from a peat swamp forest at the Real Living Lab, UNIMAS. This present study surpassed their records and supported the high diversity of scarab beetles from the limestone forests.

On the other hand, Chrysomelidae commonly known as leaf beetles are represented with at least 40,000 species from more than 2,000 genera (Muhaimin et al. 2019b). Both larvae and adult chrysomelids are herbivores which mostly feed on plant tissues, which makes them notorious agricultural pests in damaging stored products and crops (Muhaimin et al. 2019a). For example, as Temurang Cave was surrounded by plantation activities by locals along the Borneo Height highway, it is expected that this leads to the abundance of leaf beetles in the area. A similar study by Musthafa and Fauzah (2019) also recorded Chrysomelidae as the most abundant family in the lower montane forest at Fraser's Hill, where they reported a total of 115 individuals representing 14 chrysomelid species. Moreover, environmental factors such as altitude, humidity and temperature can directly affect the growth of host plants and species distribution of Chrysomelidae, particularly in high-humidity areas (Muhaimin et al. 2019a). Tenebrionidae's nocturnal, omnivorous, and non-living materials scavenger behaviours on plants and logs whether dead or alive, carcasses of dead animals, faeces, and mucus might be one of the great reasons why they were the most abundant and reported as the fourth most diverse family in this present study (Anon. 2009; Cheng et al. 2022). As for other beetle families which recorded few individuals, the occurrences of these beetles might be due to various factors but not limited to, low mobility, low positive phototaxis behaviour as well as lacking host trees and scarcity of preferred food resources in the limestone forests.

At the species level, *Triplatoma macleayi* from Erotylidae was the most abundant species with a total of 56 individuals (7.12%) collected. *Triplatoma macleayi* is one of the pleasing fungus beetles which feed on fungi that are fruiting over dead bodies of Agaricomycetes like Hymenochaetales, Polyporales, and Agaricales (Phang 2021). Normally, certain pleasing fungus beetle species only feed on certain groups of fungi specifically, although a varied fungi group can host several species in the family (Skelley 1988). Hence, it is expected that the fungus which attracts *T. macleayi* might be present around the sampling sites. Meanwhile, the second most abundant species was recorded by *Amarygmus* sp. 1 from Tenebrionidae with 39 individuals (4.96%). *Amarygmus* can be found in places where mosses are commonly distributed due to their muscivorous behaviour (Grimm 2018).

CONCLUSION

Throughout this study, 786 individuals representing 191 beetle species (56 confirmed species and 135 morpho species) from 57 subfamilies and 23 families were successfully recorded. Overall, Carabidae was recorded as the most speciose and abundant family, followed by Scarabaeidae, Chrysomelidae and Tenebrionidae. In addition to that, knowing the species diversity of beetles within limestone forests could be useful to the local authority in identifying potential hotspot area(s) for biodiversity conservation and management practice. However, comprehensive studies covering other limestone areas in the central and northern regions of Sarawak are highly recommended.

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AUTHORS DECLARATIONS

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Conflict of Interest

The authors declare that they have no conflict of interest.

Ethics Declarations
No ethical issue is required for this research.

Data Availability Statement
This is a part of Master of Science Project and the data are currently in MSc thesis entitled "Diversity and Spatial Distribution of Scarabaeidae (Insecta: Coleoptera) from Sarawak" (2023).

Authors' Contributions
TWL, SNS, AAM, ZH and RH conceived this research and designed experiments; TWL, NAZ, SNS and RH participated in the design and interpretation of the data; TWL, NAZ and SNS performed experiments and analysis; TWL, NAZ and SNS wrote the paper and participated in the revisions of it. All authors read and approved the final manuscript.

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