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# GROUND-DWELLING INSECT ASSEMBLAGES IN A SECONDARY FOREST ON A UNIVERSITY CAMPUS IN KOTA KINABALU, SABAH, MALAYSIA

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## ABSTRACT

Insect diversity in urban areas is gaining interest as people realise the influence of anthropogenic activities on these insects. However, ground insects are understudied compared to flying insects, despite their important role in ecological functions and maintaining the health of a forest ecosystem. Hence, a study on ground insect diversity was conducted in the Sustainable Forest Education and Research Area (SFERA), a forest located within a university campus in Kota Kinabalu, Sabah, Malaysia. The sampling was conducted from December 2023 until May 2024 using the Berlese-Tullgren funnel trap. A total of 3050 individuals of 85 insect species were recorded from 11 orders. The top three species-rich insect orders were Hymenoptera (44 species), Coleoptera (17 species) and Blattodea (9 species), while the Shannon-Wiener index showed that the two most diverse insect orders were Coleoptera (H' = 2.50) and Hymenoptera (H' = 2.12). In terms of feeding guild, there were four feeding guilds identified, comprising predator, decomposer, herbivore and mixed. The predatory feeding guild was the most dominant, comprising of 28.24% of the identified ground insect species. Some non-native species, consisting of the ant group, and forest specialists (ants, beetle and cockroach) groups, were also recorded in the study site. Results of this study demonstrate the importance of SFERA as an urban sanctuary for the insect communities despite the escalating pressures from landscape transformation and anthropogenic activities.

**Keywords:** Berlese-Tullgren funnel trap; SFERA@UMS; soil arthropods; urban forest

## ABSTRAK

Kepelbagaian serangga di dalam kawasan bandar semakin mendapat perhatian apabila masyarakat sedar mengenai pengaruh aktiviti antropogenik terhadap serangga. Walau bagaimanapun, serangga di permukaan tanah kurang dikaji berbanding serangga yang terbang di udara, walaupun peranan serangga tanah sangat penting untuk fungsi ekologi dan mengekalkan kesihatan ekosistem hutan. Oleh itu, satu kajian tentang kepelbagaian serangga tanah telah dijalankan di "Sustainable Forest Education and Research Area" (SFERA), iaitu sebuah hutan yang terletak di dalam kampus universiti di Kota Kinabalu, Sabah, Malaysia. Persampelan serangga dilakukan dari Disember 2023 hingga Mei 2024 dengan menggunakan perangkap corong "Berlese-Tullgren". Sejumlah 3050 individu daripada 85 spesies serangga dan 11 order telah direkodkan. Tiga order serangga yang mempunyai kekayaan spesies tertinggi ialah Hymenoptera (44 spesies), Coleoptera (17 spesies) dan Blattodea (9 spesies), manakala indeks Shannon-Wiener menunjukkan bahawa order serangga yang paling tinggi kepelbagaian ialah Coleoptera (H'=2.50) dan Hymenoptera (H'=2.12). Dari segi Kumpulan pemakanan, terdapat empat kumpulan pemakanan serangga telah dikenalpasti yang terdiri daripada pemangsa, pengurai, herbivor dan bercampur. Kumpulan pemakanan serangga pemangsa merupakan kumpulan paling dominan dan terdiri daripada 28.24% daripada spesies serangga tanah yang telah dikenalpasti. Selain itu, terdapat juga beberapa spesies bukan asli yang merupakan spesies semut serta spesies serangga hutan bandar (semut, kumbang dan lipas) yang telah dikenalpasti di kawasan kajian. Keputusan kajian ini menunjukkan kepentingan SFERA sebagai hutan perlindungan bandar untuk komuniti serangga walaupun terdapat tekanan yang semakin meningkat daripada perubahan landskap dan aktiviti antropogenik.

**Kata kunci:** Perangkap corong "Berlese-Tullgren"; SFERA@UMS; artropod tanah; hutan bandar

## INTRODUCTION

The presence of forest patches in urban landscapes is undoubtedly part of the process of fragmentation and urbanisation in a once-forested area. Forest fragmentation and disturbance alter microclimates and simplify vegetation structure. This degradation reduces ecological niches and resource availability, ultimately undermining the ecosystem functions of forests to sustain forest-dependent insect communities.

Insects, which constitute a major component of terrestrial biodiversity, are particularly sensitive to these changes because many species rely on specific host plants, microhabitats, and environmental conditions. As forest areas diminish in size and become more isolated, these ecological requirements may no longer be met, eventually leading to a loss of insect diversity and abundance (Byeon et al. 2025; Vaz et al. 2023). Moreover, insects play numerous ecological roles and occupy diverse niches (Kotze et al. 2022). Thus, it is essential to study and understand these small arthropods under urbanisation pressure.

Studies in several urban landscapes have reported declines in insect diversity following decades of the urbanisation process. Certain cities, for example, in Singapore and India, experienced a decline in insect diversity and species extirpation, due to the loss of host plants and breeding areas (Jain et al. 2018; Koparde et al. 2025; Sanchez-Bayo & Wyckhuys 2020). Such changes highlight how urban development can disrupt ecological interactions between insects and vegetation, ultimately affecting ecosystem functioning.

Despite these concerns, some studies suggested that urban forests can still support high insect diversity (Brassard et al. 2021; Morpurgo et al. 2024). The capability of urban forest fragments to sustain insect diversity depends on several factors. The effect of urbanisation on urban insect biodiversity from previous studies revealed that the species composition is related to land age and size (Sing et al. 2016), disturbance and isolation level (Jain et al. 2020; Perlik et al. 2023; Ryalls et al. 2022) and vegetation type (Jain et al. 2021; Ridzuan et al. 2021). Urban forests with greater vegetation complexity and heterogeneous microhabitats often provide more diverse resources, which can support a wider range of insect taxa.

In Malaysia, studies of insect diversity in urban forests remain scarce and fragmented in scope. Some have focused on single conspicuous taxonomic groups, particularly grasshoppers (Rahim et al. 2024), stingless bees (Hamid et al. 2016), dung beetles (Muhaimin et al. 2015) and butterflies (Jasmani et al. 2022; Nordin et al. 2025). Research focusing specifically on general insect communities is still limited. Khadijah et al. (2013) conducted a comprehensive survey of the general insect diversity in Kota Damansara Community Forest Reserve in five days, yet they used various sampling methods: manual collection, light trap, malaise traps and pitfall traps. Naim et al. (2019) also conducted a 10-week general insect diversity survey using combinations of pitfall traps, light traps, yellow-pan traps and sweep nets. A study by Jusoh & Hashim (2016), provided an important baseline information by examining general ground insects using pitfall traps, but their sampling was less than a month and focused exclusively on distance-to-edge effects.

This lack of information regarding ground insect communities in urban forest landscapes affects the conservation efforts for insect diversity within urban forests. Ground insects are fundamentally important to the forest ecosystem, especially in the "behind-the-scenes" mechanics of nature, when they are closely associated with soil and litter. For instance, detritivore insects such as termites (Blattodea) and certain beetles from the Tenebrionidae family feed on dead plant materials, and the feeding process of fragmenting the material accelerates the microbial decomposition (Louzada & Nichols 2012). Frass produced from herbivores, such as grasshoppers (Orthoptera) and caterpillars (Lepidoptera), would also stimulate nutrient cycling activity besides affecting plant growth and regeneration on the forest floor (Kristensen et al. 2019). Through these diverse functional role examples, these ground insects are the key drivers in nutrient cycling and soil fertility, whose presence contributes to the ecosystem resilience even under unsteady conditions faced by urban forests (Mahmood et al. 2026).

Additionally, predatory taxa in some ant species (Formicidae), beetles (Carabidae and Staphylinidae) and mantis (Mantodea) regulate the ground invertebrates' population, contributing to trophic interactions (Dejean et al. 2024; Thanuja et al. 2025). Ground insects are also a primary food source for larger urban wildlife, such as birds, frogs and reptiles (de Andrade 2019; Santana et al. 2019; Seress et al. 2020). One of the obvious examples was the record of the Sunda pangolin (*Manis javanica*) that was spotted foraging on the termite mounds in this study's sampling site (Sompud et al. 2023).

Besides the various roles of ground insects, these insects are ecosystem indicators as they reflect the urban conditions. Different studies have reported the impact of urban effects on ground insects, including the urban heat island affecting the body size of ground beetles (Lövei & Magura 2022) and soil compaction affecting cicada nymphs to burrow (Moriyama & Numata 2015). Hence, information gathered on the diversity and role of ground insects provides a better understanding of how to better manage these green spaces to ensure they continue to provide a beneficial service to the city. In addition, it provides the local authorities with the evidence needed to protect urban green belts

To fill this gap, this study aimed to document the ground insect diversity in an urban forest within a Malaysian university campus as a case study. This study used Berlese-Tullgren funnel traps to capture a general representation of the ground insect community in the forest litter layer. This layer was selected for sampling because it represents the primary zone of organic matter accumulation and biological activity on the forest floor. Most organic inputs, including dead plant materials, seeds, and animal remains, are deposited on the ground surface before decomposition and incorporation into the soil. This layer, therefore, provides a platform for all sorts of ground insects, which investigates the functional composition of the assemblages.

## MATERIALS AND METHODS

### Study Site

The ground insect sampling was conducted from December 2023 to May 2024 in the Sustainable Forest Education and Research Area (SFERA), which is located within the Universiti Malaysia Sabah (UMS) campus in Kota Kinabalu, Sabah, Malaysia. SFERA was designated to the Faculty of Tropical Forestry in 2022. The entire area covers 25 hectares and represents a secondary forest dominated by *Acacia auricoliformis* and *Acacia mangium* within the UMS campus. Although the whole forest is an *Acacia*-dominated secondary forest ecosystem, SFERA is still rich in plant and wildlife species (Lee et al. 2024; Lim et al. 2023; Majuakim et al. 2018; Sugawara et al. 2009). Besides being surrounded by university buildings and infrastructure, the forest also connects to the nearby Bukit UMS forested hill as well as two neighbouring villages (Kampung Kebagu and Kampung Selembangun).

Since the establishment of SFERA in 2022, many enrichment planting events have been conducted to enrich the *Acacia*-dominated forest. Various tree species, consisting of Dipterocarps and local fruit tree species, were gradually introduced into SFERA as part of the forest restoration and enrichment planting initiatives. Among the forest tree species planted were *Dryobalanops lanceolata*, *Terminalia copelandii* and *Hopea sangal*, while the fast-growing timber species planted consists of *Neolamarckia cadamba* and *Octomeles sumatrana*. The fruit tree species consist of *Mangifera indica* and *Nephelium lappaceum*.

Three 100m$^2$-sized sampling plots were established as the insect sampling sites within the SFERA area (Figure 1). The plots were located approximately 100m apart from each other and were established following enrichment planting activities conducted within SFERA. Plant species planted for enrichment in these plots were *Durio zibethinus*, *Artocarpus heterophyllus*, *Artocarpus integer* and *Artocarpus odoratissimus*. Additionally, these plots were situated within similar habitat conditions and were not intended to represent contrasting habitat types. These sampling plots are situated at an elevation of approximately 45 - 86m above sea level and the soil type predominantly consists of sandy and loam mixture.


Figure 1. Location of the three sampling plots within the Sustainable Forest Education & Research Area (white boundary line) of Universiti Malaysia Sabah (red boundary line)

**Insect Sampling Method**
Each sampling plot contained nine organic-layer collection points. These points were randomly selected during each sampling event and were positioned at least 5 to 10 meters apart from each point. Sampling was conducted three times per month in each plot. At each sampling point, the organic litter layer (including leaves, twigs, and loose humus) within a 50 x 50 cm quadrate was sampled (Martelli et al. 2004). The organic samples were brought back to the Entomology Laboratory of the Faculty of Tropical Forestry, UMS.

The litter samples were placed in Berlese–Tullgren funnel traps for 24 to 48 hours, or until the litter material was completely dry, as determined by hand feel. Occasional stirring of the organic matter was performed to encourage even drying of the materials and to induce insects to move down the funnel traps, which were preserved in a 70% alcohol-filled collection bottle at the base of the traps' funnels (Guenard & Lucky 2011). Due to the limited funnel traps, each organic matter samples were processed by two different sized funnels: One with a 5mm mesh hole sieve size of 27cm diameter, 9.5cm depth and heated with a 25W incandescent bulb; while one with a 5mm mesh hole sieve size of 46cm diameter and 15cm depth and heated with a 40W incandescent bulb.

**Specimen Identification and Feeding Guild Sorting**
Insect specimens were sorted and deposited in the Entomology Laboratory of the Faculty of Tropical Forestry, UMS. Specimens were identified to species level if possible, using relevant references, mainly based on Mohamed (1999). The termite specimens were identified based on Gan & Homathevi (2023). Ants were identified with the dichotomous key by Fayle et al. (2014), with pictorial aids of AntWeb (n.d.). Grasshoppers were identified based on Tan (2012) and Tan & Kamaruddin (2014).

Feeding guilds were assigned based on the most precise taxonomic identification achievable for each specimen, including Rinker & Lowman (2004), Greer & Moreau (2021) and Potapov et al. (2022). Specimens that could not be identified to family-level or morphospecies were categorised under an unknown feeding guild. In addition, when feeding habits were variable or uncertain within an identified taxonomic group due to insufficient feeding ecology literature support, the guild was also recorded as unknown. For example, feeding guilds for morphospecies under families Carabidae and Coccinellidae were assigned as unknown because some species exhibit herbivorous or carnivorous feeding strategies (Huang et al. 2025; Kulkarni et al. 2015).

**Data Analysis**
Diversity indices comprising Shannon-Wiener (H'), Margalef's species richness (Dmg), Pielou's evenness (J), Berger-Parker dominance index (d) and Chao-1 species estimation were calculated according to each insect order, using R software version 4.4.2. The diversity estimation using rarefaction and extrapolation sampling curves was generated from the iNEXT online tool (latest version 30 March 2024) developed by Chao et al. (2016) and based on Chao et al. (2014).

## RESULTS AND DISCUSSION

A total of 85 species from 11 insect orders were recorded, with the top two richest orders being Hymenoptera (44 species) and Coleoptera (17 species), as shown in Figure 2. In terms of species abundance, a total of 3050 individuals of insects were collected. The top three most abundant orders were Hymenoptera (1820 individuals), Blattodea (643 individuals) and

Lepidoptera (198 individuals), as shown in Figure 3. Overall, Hymenoptera is the most diverse and abundant insect group in SFERA.

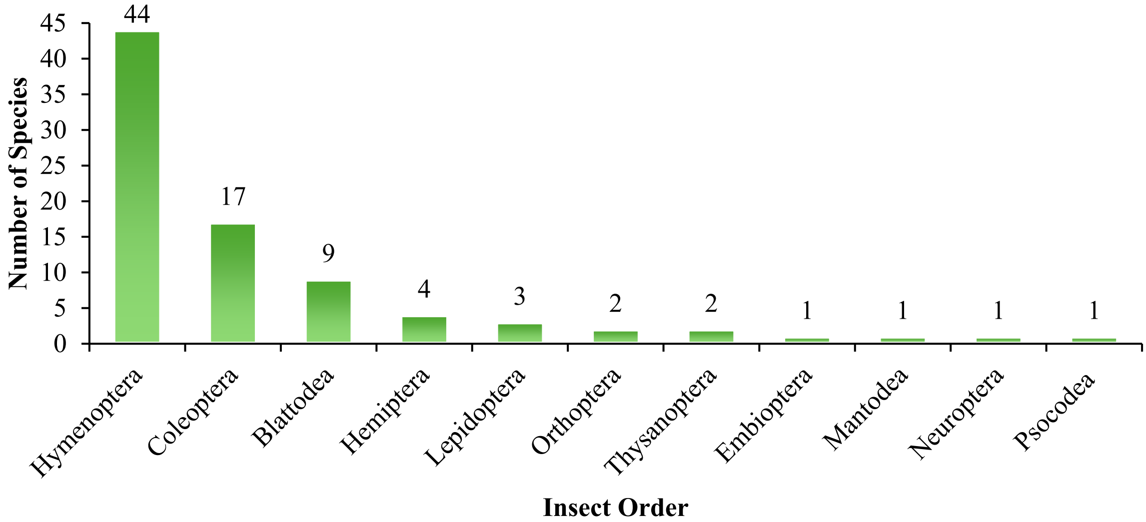


Figure 2. Number of insect species recorded in each insect order

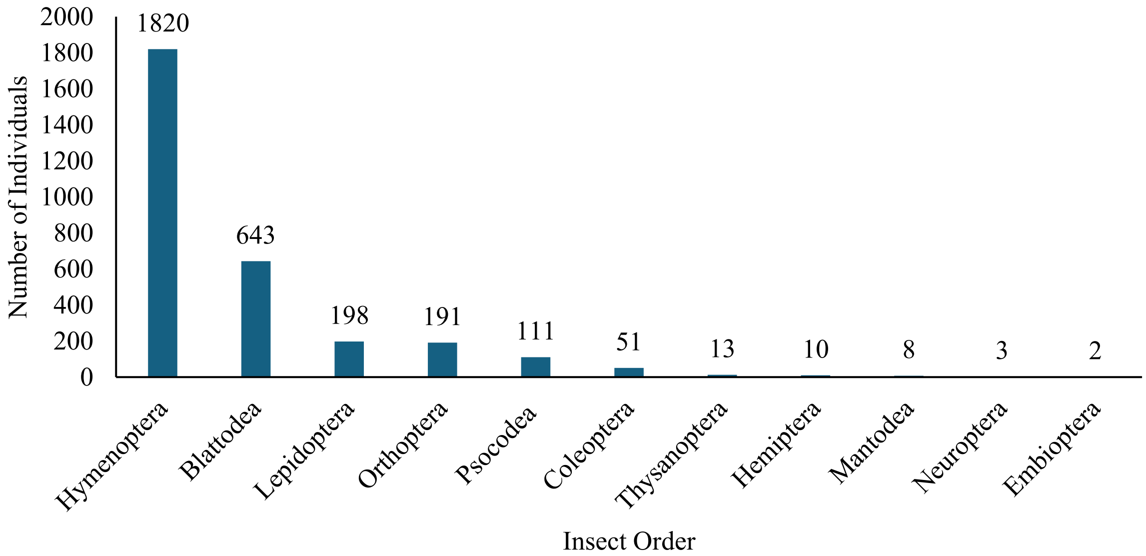


Figure 3. Number of individuals recorded in each insect order

At the family level, the ants, Formicidae (Order: Hymenoptera), were recorded as the most diverse and richest insect family, with 42 species of 1818 individuals. Similar findings were also reported by Jusoh & Hashim (2016) in their studies conducted in two urban forests located in Kuala Lumpur. This situation happens due to the resilience of ants in urban areas and their ability to form new colonies through fission and budding events in a short time, that allows their population to rapidly expand to new areas (Choe 2019; Hovestadt et al. 2024; Shimoji et al. 2022). Despite its huge abundance, the ecosystem functions and services provided by the ant communities should be noted, as they act as seed dispersers, soil engineers, scavengers and also biological pest control agents (Perfecto & Philpott 2023).

The species abundance rank of each species is illustrated in Figure 4 and listed in Table 1. The top three most abundant species were *Nylanderia kraepelini* (Hymenoptera: Formicidae, 925 individuals, Rank 1), *Macrotermes gilvus* (Blattodea: Termitidae, 334 individuals, Rank 2) and *Microcerotermes* sp. (Blattodea: Termitidae, 233 individuals, Rank 3).

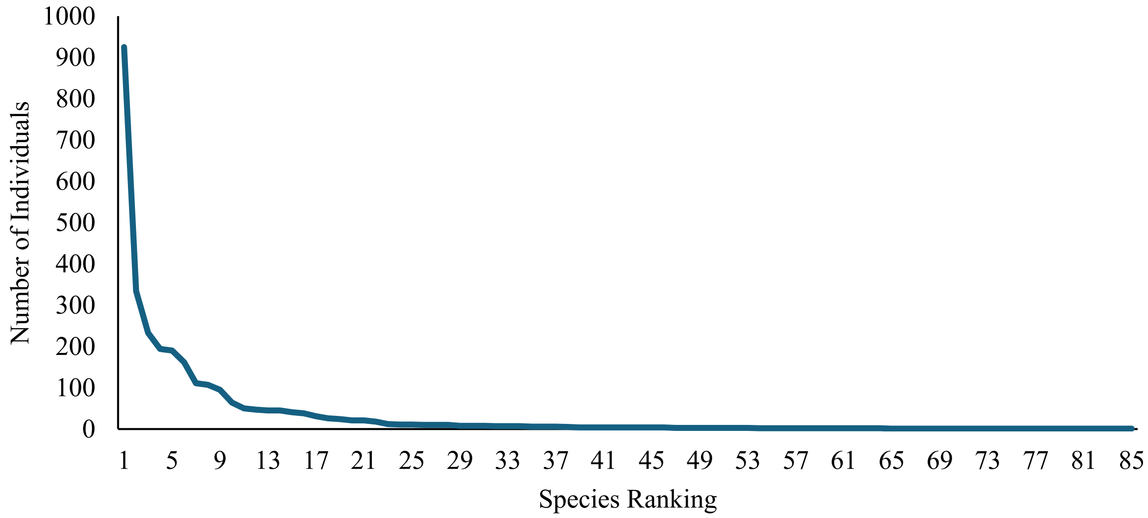


Figure 4. Species abundance rank of each species

Table 1. Species abundance rank and feeding guild of each species

| Rank | Order | Family | Species | Abundance | Feeding Guild |
|---|---|---|---|---|---|
| 1 | Hymenoptera | Formicidae | *Nylanderia kraepelini* | 925 | Mixed |
| 2 | Blattodea | Termitidae | *Macrotermes gilvus* | 334 | Decomposer |
| 3 | Blattodea | Termitidae | *Microcerotermes* sp. | 233 | Decomposer |
| 4 | Lepidoptera | Morpho | Morpho sp. 2 | 194 | Unknown |
| 5 | Orthoptera | Mogoplistidae | Morpho sp. 1 | 190 | Unknown |
| 6 | Hymenoptera | Formicidae | *Plagiolepis alluaudi* | 162 | Mixed |
| 7 | Psocodea | Morpho | Morpho sp. | 111 | Unknown |
| 8 | Hymenoptera | Formicidae | *Technomyrmex kraepelini* | 107 | Mixed |
| 9 | Hymenoptera | Formicidae | *Monomorium floricola* | 95 | Mixed |
| 10 | Hymenoptera | Formicidae | *Brachyponera luteipes* | 64 | Mixed |
| 11 | Hymenoptera | Formicidae | *Carebara pygmaea* | 50 | Predator |
| 12 | Hymenoptera | Formicidae | *Pheidole parva* | 47 | Mixed |
| 13 | Hymenoptera | Formicidae | *Monomorium pharaonis* | 45 | Mixed |
| 14 | Hymenoptera | Formicidae | *Strumigenys* sp. 1 | 45 | Predator |
| 15 | Hymenoptera | Formicidae | *Tapinoma melanocephalum* | 41 | Mixed |
| 16 | Hymenoptera | Formicidae | *Pheidole* sp. 1 | 38 | Mixed |
| 17 | Blattodea | Blaberidae | *Pseudophoraspis nebulosa* | 31 | Decomposer |
| 18 | Blattodea | Termitidae | *Nasutitermes havilandi* | 26 | Decomposer |

| Rank | Order | Family | Species | Abundance | Feeding Guild |
|---|---|---|---|---|---|
| 19 | Hymenoptera | Formicidae | *Hypoponera lumpurensis* | 24 | Predator |
| 20 | Hymenoptera | Formicidae | *Odontoponera denticulata* | 21 | Predator |
| 21 | Hymenoptera | Formicidae | *Technomyrmex sundaicus* | 21 | Mixed |
| 22 | Hymenoptera | Formicidae | *Crematogaster ampullaris* | 18 | Mixed |
| 23 | Hymenoptera | Formicidae | *Diacama rugosum* | 12 | Predator |
| 24 | Hymenoptera | Formicidae | *Dolichoderus taprobanae* | 11 | Mixed |
| 25 | Thysanoptera | Morpho | Morpho sp. 2 | 11 | Unknown |
| 26 | Blattodea | Blaberidae | Morpho sp. 1 | 10 | Unknown |
| 27 | Coleoptera | Curculionidae | *Coccotrypes* sp. | 10 | Herbivore |
| 28 | Hymenoptera | Formicidae | *Carebara affinis* | 10 | Predator |
| 29 | Hymenoptera | Formicidae | *Colobopsis vitrea* | 8 | Mixed |
| 30 | Hymenoptera | Formicidae | *Hypoponera pygmaea* | 8 | Predator |
| 31 | Mantodea | Gonypetidae | *Amantis reticulata* | 8 | Predator |
| 32 | Coleoptera | Carabidae | Morpho sp. 2 | 7 | Unknown |
| 33 | Coleoptera | Carabidae | Morpho sp. 3 | 7 | Unknown |
| 34 | Hymenoptera | Formicidae | *Cardiocondyla wroughtonii* | 7 | Mixed |
| 35 | Coleoptera | Carabidae | Morpho sp. 1 | 6 | Unknown |
| 36 | Hymenoptera | Formicidae | *Anochetus graeffei* | 6 | Predator |
| 37 | Hymenoptera | Formicidae | *Camponotus reticulatus* | 6 | Mixed |
| 38 | Hymenoptera | Formicidae | *Strumigenys emmae* | 5 | Predator |
| 39 | Blattodea | Ectobiidae | *Hemithyrsocera histrio* | 4 | Decomposer |
| 40 | Hemiptera | Morpho | Morpho sp. | 4 | Unknown |
| 41 | Hymenoptera | Formicidae | *Hypoponera javana* | 4 | Predator |
| 42 | Hymenoptera | Formicidae | *Lioponera suscitata* | 4 | Predator |
| 43 | Hymenoptera | Formicidae | *Mystrium camillae* | 4 | Predator |
| 44 | Hymenoptera | Formicidae | *Myrmoteras diastematum* | 4 | Predator |
| 45 | Hymenoptera | Formicidae | *Strumigenys* sp. 2 | 4 | Predator |
| 46 | Hymenoptera | Formicidae | *Tetramorium bicarinatum* | 4 | Predator |
| 47 | Coleoptera | Curculionidae | Morpho sp. 1 | 3 | Unknown |
| 48 | Coleoptera | Staphylinidae | Morpho sp. 2 | 3 | Unknown |
| 49 | Hemiptera | Aradidae | Morpho sp. | 3 | Unknown |
| 50 | Hymenoptera | Formicidae | *Carebara (Oligomyrmex)* sp. | 3 | Predator |
| 51 | Hymenoptera | Formicidae | *Paratrechina longicornis* | 3 | Mixed |
| 52 | Lepidoptera | Geometridae | Morpho sp. | 3 | Unknown |
| 53 | Neuroptera | Myrmeleontidae | Morpho sp. | 3 | Unknown |
| 54 | Blattodea | Ectobiidae | *Hemithyrsocera* sp. | 2 | Decomposer |
| 55 | Blattodea | Rhinotermitidae | *Schedorhinotermes* sp. | 2 | Decomposer |
| 56 | Coleoptera | Carabidae | Morpho sp. 4 | 2 | Unknown |
| 57 | Coleoptera | Staphylinidae | Morpho sp. 5 | 2 | Unknown |
| 58 | Coleoptera | Staphylinidae | Morpho sp. 7 | 2 | Unknown |
| 59 | Coleoptera | Curculionidae | Morpho sp. 2 | 2 | Unknown |
| 60 | Embioptera | Morpho | Morpho sp. 1 | 2 | Unknown |
| 61 | Hemiptera | Cydnidae | Morpho sp. | 2 | Unknown |

| Rank | Order | Family | Species | Abundance | Feeding Guild |
|---|---|---|---|---|---|
| 62 | Hymenoptera | Formicidae | *Cataulacus latissimus* | 2 | Mixed |
| 63 | Hymenoptera | Formicidae | *Leptogenys peuqueti* | 2 | Predator |
| 64 | Thysanoptera | Morpho | Morpho sp. 1 | 2 | Unknown |
| 65 | Blattodea | Blaberidae | *Perisphaerus* sp. | 1 | Decomposer |
| 66 | Coleoptera | Coccinellidae | Morpho sp. | 1 | Unknown |
| 67 | Coleoptera | Curculionidae | *Xyleborus* sp. | 1 | Decomposer |
| 68 | Coleoptera | Hybosoridae | *Madrasostes* sp. | 1 | Decomposer |
| 69 | Coleoptera | Staphylinidae | Morpho sp. 1 | 1 | Unknown |
| 70 | Coleoptera | Staphylinidae | Morpho sp. 3 | 1 | Unknown |
| 71 | Coleoptera | Staphylinidae | Morpho sp. 4 | 1 | Unknown |
| 72 | Coleoptera | Staphylinidae | Morpho sp. 7 | 1 | Unknown |
| 73 | Hemiptera | Morpho | Morpho sp. | 1 | Unknown |
| 74 | Hymenoptera | Bethylidae | Morpho sp. | 1 | Unknown |
| 75 | Hymenoptera | Formicidae | *Hypoponera* sp. | 1 | Predator |
| 76 | Hymenoptera | Formicidae | *Oecophylla smaragdina* | 1 | Mixed |
| 77 | Hymenoptera | Formicidae | *Polyrhachis vindex* | 1 | Mixed |
| 78 | Hymenoptera | Formicidae | *Prionopelta kraepelini* | 1 | Predator |
| 79 | Hymenoptera | Formicidae | *Pseudoneoponera tridentata* | 1 | Predator |
| 80 | Hymenoptera | Formicidae | *Strumigenys (Pyramica)* sp. | 1 | Predator |
| 81 | Hymenoptera | Formicidae | *Strumigenys propinqua* | 1 | Predator |
| 82 | Hymenoptera | Formicidae | *Tetramorium insolens* | 1 | Predator |
| 83 | Hymenoptera | Torymidae | Morpho sp. | 1 | Unknown |
| 84 | Lepidoptera | Morpho | Morpho sp. 1 | 1 | Unknown |
| 85 | Orthoptera | Mogoplistidae | Morpho sp. 2 | 1 | Unknown |

In terms of the insect feeding guild, there were four feeding guilds identified among the recorded insects: predator, decomposer, herbivore and mixed, as tabulated in Table 2. Due to the lack of available identification keys and taxonomic literature that limited the precise species-level identification of 31 ground dwelling insect species, these insects were thus classified into the "unknown" feeding guild.

Table 2. Number of species and individuals according to insect feeding guild

| Feeding Guild | Number of Species | Number of Individuals |
|---|---|---|
| Decomposer | 10 (11.76%) | 635 (20.82%) |
| Herbivore | 1 (1.18%) | 10 (0.33%) |
| Mixed | 19 (22.35%) | 1602 (52.52%) |
| Predator | 24 (28.24%) | 224 (7.34%) |
| Unknown | 31 (36.47%) | 579 (18.98%) |
| **Total** | **85** | **3050** |

Values in parentheses indicate relative percentages of the total.

Among the feeding guilds, predatory insects represented the largest proportion of identified species richness, comprising 24 ground insect species (28.24% of the total species) and 224 individuals (7.34% of the total abundance). The predators included mantis (Mantodea), and several ant species from Hymenoptera, which are important biological control agents to control the herbivory group (Baruah & Bera 2024).

Another 10 species (11.76% of the total species) of 635 individuals (20.82% of the total abundance) were identified as decomposers that primarily comprised of insects from the orders Blattodea and Coleoptera. These insects play crucial roles in the decomposition of organic matter within the litter layer. By breaking down leaf litter and other organic materials, decomposers facilitate nutrient cycling and contribute to soil formation and fertility (Rupali et al. 2024).

Herbivorous insects were poorly represented in the present study, accounting for only one species with 10 individuals. This pattern is likely influenced by the sampling method, which mainly targets litter and soil-associated species rather than foliage-associated ones. Despite the low representation, herbivorous insects still play important ecological roles in insect-plant interactions, including nutrient cycling (Schuldt et al. 2011), plant growth regulation and maintaining plant diversity (Agrawal & Maron 2022).

Although only 19 insect species were categorised into the mixed-feeding guild, this guild recorded the highest abundance, accounting for half of the total individuals counted (1602 individuals, 52.52% of total abundance). Notably, all species in this feeding guild were from the Order Hymenoptera, specifically the family Formicidae (ants). The mixed-feeding guild, or omnivorous, reflects the diverse and flexible trophic ecology of ants, as many would consume prey, nectar, seeds, and organic detritus depending on the resource availability. Generally, urban forests or habitats often favour generalists that can exploit a broad range of resources, while specialist populations may decline due to habitat alteration and reduced niche availability (Silva et al. 2026).

The dominance of ants in the mixed feeding guild in this study may be further amplified by the vegetation in SFERA. This urban forest is mainly dominated by the *Acacia* tree species, likely established through natural succession in this degraded forest. These non-native invasive trees are known to create relatively homogeneous stand structures, with simplified understory vegetation and litter layer composition (Lee et al. 2021). The homogeneity in habitat structure may reduce species or individuals with specific feeding guilds that depend on specific host plants, prey or microclimate conditions. Thus, being a mixed feeding guild allowed higher survival by access to different resources instead of relying on a single resource type in a limited and homogenous environment (McKinney 2006). Moreover, having species or individuals with mixed feeding guild in an ecosystem provides an insurance against species loss or population change of specific feeding guilds, such as purely predatory and herbivory, thus ensuring the stability of urban forest ecosystem functions (Biggs et al. 2020; Fischer & de Bello 2023).

Generally, the ground insect community in SFERA exhibited a Shannon-Wiener index value of H'=2.80 and Margalef's richness index of Dmg=10.47 (Table 3). However, the recorded diversity also showed a moderately uneven distribution of populations (J=0.63 and d=0.30), due to the high abundance of the top three abundant insect species (*N. kraepelini*, *M. gilvus* and *Microcerotermes* sp.). The high abundance is commonly observed in social insects such as ants and termites due to their colonial lifestyle and large colony sizes. In addition, the collection of the litter layer for extraction in the Berlese-Tullgren traps may favour the collection of insects that occur in high densities within the litter layer.

Table 3. Insect diversity indices according to each insect order

| **Order** | **Shannon-Wiener (H')** | **Margalef Richness (Dmg)** | **Pielou's Evenness (J)** | **Berger-Parker (d)** |
|---|---|---|---|---|
| Overall | 2.80 | 10.47 | 0.63 | 0.30 |
| Blattodea | 1.13 | 1.24 | 0.51 | 0.52 |
| Coleoptera | 2.50 | 4.07 | 0.88 | 0.20 |
| Hemiptera | 1.28 | 1.30 | 0.92 | 0.40 |
| Hymenoptera | 2.12 | 5.73 | 0.56 | 0.51 |
| Others | 1.33 | 1.60 | 0.56 | 0.37 |

Among the insect orders, Coleoptera recorded the highest Shannon-Wiener index of H'=2.50, with Margalef richness of Dmg=4.07 and evenness of J=0.88, thus showing that Coleoptera is a diverse order in SFERA. Hymenoptera recorded the highest species richness with Margalef's richness index (Dmg=5.73), mainly due to the high number of ant species recorded. On the contrary, Hymenoptera recorded a lower Shannon-Wiener index (H'=2.12) and evenness (J=0.56) due to the high abundance of several ant species, especially *N. kraepelini*. Despite a low diversity (H'=1.13) and species richness ($D_{mg}$=1.24), Blattodea displayed a moderate evenness and dominance index (J=0.51 and d=0.52), as the Blattodea diversity in SFERA was dominated by two abundant termite species, *M. gilvus* and *Microcerotermes* sp.

The Hemiptera order recorded a low diversity and species richness; H'=1.28 and Dmg=1.30, despite very high evenness of J=0.92, with only four recorded species, which were *Riptortus* sp. (4 individuals), Aradidae: Morpho sp. (3 individuals), Cydnidae: Morpho sp. (2 individuals) and Morpho sp. (1 individual). The remaining insect orders were grouped as 'others' due to the low species number recorded in each order.

Based on the recorded diversity, Chao-1 estimated the existence of 105 species in SFERA, as shown in Figure 5, which is 20 species more than the recorded number of 85 species. Although the sampling coverage curve reached an asymptote after six months of sampling, indicating that the majority of commonly occurring species had been recorded, this does not imply a complete inventory of the ground insect community (Schmitz & Rahmann 2025). The additional 20 species predicted by Chao-1, therefore, represent species that are rare, low abundance, less active or patchily distributed. Even though seasonal variation was not covered in this study, it is known to influence species activity and detectability, as different species react differently under varying environmental conditions such as rainfall and temperature (Guezen & Anand 2025; Ulrich & Sargent 2025), where some would migrate, aestivate or hide deep into soil (Azevedo et al. 2020). Therefore, a longer sampling period is highly recommended.

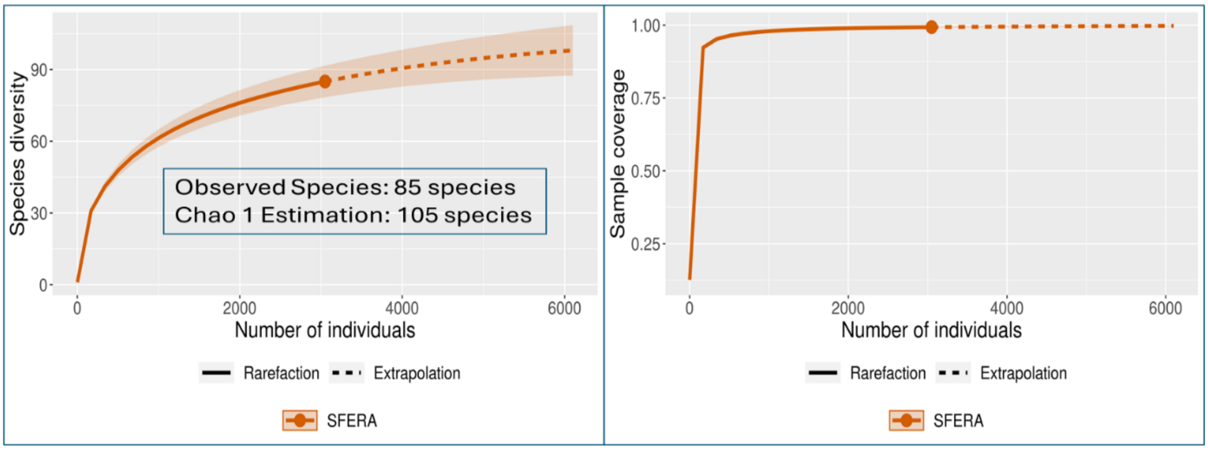


Figure 5. Species estimation curve (left) and sampling coverage (right) based on species abundance data

The insect assemblage recorded in SFERA comprised of species with different biogeographic origins and ecological preferences, including widely distributed cosmopolitan taxa and species commonly associated with forest habitats. There were five ant species listed as being widely distributed around the world and frequently associated with human-modified environments, including *Tapinoma melanocephalum*, *Monomorium floricola*, *Monomorium pharaonis*, *Paratrechina longicornis* and *Strumigenys emmae*. The *T. melanocephalum* and *M. floricola* were native to Malaysia and the Borneo region (Wetterer 2009; Wetterer 2010a); the origins of *M. pharaonis* and *P. longicornis* were unknown, yet widespread around the world (Wetterer 2008; Wetterer 2010b); while *S. emmae* originated from Australia and was first recorded in Malaysia in 1946 (Wetterer 2012). These species are often recorded in indoor or urban settings and are widely regarded as tramp or urban-associated species (Loke & Lee 2004; Na & Lee 2001). The presence of non-native species in urban forests poses a substantial threat to local forest landscapes and native biodiversity (Li et al. 2020). SFERA may face similar pressures, as urban forests are one of the potential contact points for unintentional introduction of foreign species through landscaping and goods delivery.

Interestingly, several species typically associated with forest habitats were also recorded in this present study, including *Leptogenys peuqueti*, *Pseudoneoponera tridentata*, *Strumigenys* spp., *Madrasostes* sp. and *Pseudophoraspis nebulosa*. These species have been reported present in fragmented urban forest environments from previous studies around Malaysia and Singapore (Ballerio & Maruyama 2010; Ho et al. 2019; Tan & Lim 2013; Yamane et al. 2018; Yamane et al. 2021). These species are associated with leaf litter or ground microhabitats, suggesting their preference for forest floor environments. However, their preference in SFERA does not necessarily indicate strict habitat specialisation, as some species have also been observed in secondary or urban forest ecosystems, indicating a degree of ecological flexibility. For example, *L. peuqueti* has been recorded in both primary rainforest and urban forest habitats in Sabah, Malaysia (Bakhtiar & Chiang 2015).

A native ant species *Oecophylla smaragdina*, was also represented in the assemblage (Wetterer 2017). Although typically associated with arboreal habitats in natural forests (Bluthgen & Fiedler 2002), this species is also commonly found in managed landscapes such as fruit orchards and oil palm plantations (Exelis et al. 2025; Samal & Kumar 2024), suggesting its tolerance to a certain level of disturbance. This highlights that native species are not necessarily restricted to undisturbed habitats and may persist or even thrive in modified environments.

Findings of this study reveals a highly heterogeneous ant community within SFERA, characterized by the coexistence of forest-associated specialists, disturbance-tolerant natives, and cosmopolitan urban-associated species that is shaped by both remnant forest microhabitats and urban influences. This condition may be related to its relatively low historical disturbance prior to gazettement, even after the founding of the university compound in 1995, which has allowed the retention of native vegetation, microclimatic conditions and structural features such as dead wood, crevices, and leaf litter that provide important habitats for ground-dwelling insects. These factors facilitate the persistence of forest-associated species despite the surrounding urbanisation, although this was not directly investigated in the present study.

## CONCLUSION

In conclusion, the results of this study recorded 85 species of ground insects from 11 orders. The overall ground insect diversity in SFERA recorded a Shannon-Wiener index of H’=2.80, Margalef richness index of Dmg=10.47, Pielou’s evenness index of J=0.63 and Berger-Parker dominance index of d=0.30. These values indicate that SFERA has a relatively species-rich ground insect assemblage with moderately uneven abundance distribution, where several species contributed disproportionately to the total number of individuals. The presence of forest-associated species highlights the importance of appropriate urban forest management in SFERA for biodiversity conservation. The ecological impacts of the non-native insect species within SFERA which has not been assessed underscores the importance of monitoring potential negative effects on the native communities. The protection and maintenance of ground insect diversity is highly recommended, with some suggestions: setting up restricted areas to avoid disturbing the ground and maintaining the leaf litter cover and decaying woods that provide important microhabitats for ground insects.

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## AUTHORS DECLARATION

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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. In addition, the research permit was granted by the Sabah Biodiversity Council c/o Sabah Biodiversity Centre, under license reference number: JKM/MBS.1000-2/2 JLD. 18(81).

**Data Availability Statement**
This is part of the MSc research work. The authors confirm that the data supporting the findings are available in this article.

**Authors' Contributions**
GLZY and MLTL conceived this research and designed the sampling; GLZY performed the sampling and data analysis; GLZY and MLTL participated in the data interpretation, wrote and revised the paper.

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