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AN INSIGHT INTO THE DISTRIBUTION OF PYGMY GRASSHOPPERS (ORTHOPTERA: TETRIGIDAE) IN THE KLANG VALLEY, MALAYSIA

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ABSTRACT

The ecology of pygmy grasshoppers in Southeast Asia is generally understudied, especially in rapidly developing areas in Malaysia. This study aims to record the species assemblage and investigate the habitat preferences of pygmy grasshoppers in selected locations across the Klang Valley, Malaysia. Overall results recorded 16 Tetrigidae species from three subfamilies (Metrodorinae, Tetriginae and Sceliminninae) and two tribes (Criotettigini and Thoradontini). Among these, nine species exhibited a preference for forest environments, while three species demonstrated an affinity for urban habitats. Four species can adapt to both habitat types, signifying their greater tolerance towards environmental pressure. Unweighted Pair Group Method with Arithmetic Mean (UPGMA) dendrogram based on Jaccard similarity coefficient showed distinct clusters between urban and forested habitats in terms of the species composition, supported by the result of the nonmetric multidimensional scaling (NMDS) analysis. *Systolederus cinereus* and *Bolivaritettix* sp. are widely distributed as it can be found at most of the studied locations. It is also found that species presence is highly influenced by the habitats' environmental conditions as 13 out of 16 species were present in the forested habitats. Based on these findings, pygmy grasshoppers have the potential to become bioindicators for the environment, owing to their sensitivity to habitat conditions.

Keywords: Biological indicator, habitat preferences, species diversity, urban ecology, urban heat island

ABSTRAK

Ekologi Belalang Pigmi di Asia Tenggara secara umumnya masih kurang dikaji, terutamanya di kawasan yang pesat membangun di Malaysia. Kajian ini bertujuan untuk merekodkan kehadiran spesies dan mengkaji kecenderungan habitat Belalang Pigmi di lokasi terpilih di seluruh Lembah Klang, Malaysia. Hasil kajian merekodkan 16 spesies Tetrigidae daripada tiga subfamili (Metrodorinae, Tetriginae dan Sceliminae) dan dua tribe (Criotettigini dan Thoradontini). Daripada jumlah tersebut, sembilan spesies lebih cenderung kepada persekitaran hutan, manakala tiga spesies cenderung kepada habitat bandar. Empat spesies boleh menyesuaikan diri dengan kedua-dua jenis habitat, menunjukkan tahap toleransi yang tinggi terhadap tekanan persekitaran. Dendrogram *Unweighted Pair Group Method with Arithmetic Mean* (UPGMA) berdasarkan pekali keserupaan Jaccard menunjukkan kluster berbeza antara habitat bandar dan habitat hutan dari segi komposisi spesies, yang mana hasil ini disokong oleh keputusan analisis *nonmetric multidimensional scaling* (NMDS). *Systolederus cinereus* dan *Bolivaritettix* sp. mempunyai taburan yang menyeluruh kerana ianya boleh didapati di kebanyakan lokasi kajian. Hasil kajian juga mendapati bahawa kehadiran spesies sangat dipengaruhi oleh keadaan persekitaran kerana 13 daripada 16 spesies dapat ditemui di habitat hutan. Berdasarkan penemuan ini, Belalang Pigmi berpotensi untuk menjadi bioindikator alam sekitar, jika kepekaan terhadap keadaan persekitaran diambil kira.

Katakunci: Penunjuk biologi, keutamaan habitat, kepelbagaian spesies, ekologi bandar, pulau haba bandar

INTRODUCTION

The Tetrigidae, or pygmy grasshoppers, are a monophyletic clade and form a unique lineage among the Caelifera (Song et al. 2015). Although the Tetrigidae in Peninsular Malaysia is gaining attention recently (Muhammad et al. 2018, Muhammad et al. 2023) there is still a dearth of information on them, especially in rapidly urbanising areas such as the Klang Valley. Quantitative studies on the habitat association of pygmy grasshoppers are restricted to a few species in the temperate region (Gröning et al. 2007; Hochkirch et al. 2000; Kuřavová & Kočárek 2015) and are even fewer in Southeast Asia (Tan et al. 2017).

Tetrigidae is an ancient group of grasshoppers and like many other insects, have associations and preferences for specific microhabitats and habitats. They can generally be found on the forest floor, tree trunks, low plant community, among leaf litter and rocky river but certain species may exhibit preferences for specific microhabitats (Muhammad et al. 2023; Neo et al. 2024; Tan et al. 2017). Amédégnato and Devriese (2008) considered most species of pygmy grasshoppers as limno-terrestrial that require an aqueous matrix (moist areas) in strictly terrestrial habitats while some are more dependent on water.

Despite their common occurrence in the forests, they are also present in the urban habitats, which are altered landscapes prone to disturbances (Ancillotto & Labadessa 2024; Pernat et al. 2024). In contrast to the stable environmental condition of the forests, the urban landscapes are harsh due to the limited supply of food and shelter. Thus, we believe that apart from biotic factors, abiotic factors might also play a vital role in determining the distribution and assemblage of pygmy grasshoppers in the urban environment.

Hence, this study aims to record the species assemblage between urban and forested habitats and investigate the habitat preferences of pygmy grasshoppers in the selected locations across the Klang Valley. Here, we list the Tetrigidae species present in 1) urban (high disturbance), 2) forested (low disturbance) habitats, and in both habitat types. The association of the pygmy grasshoppers with the temperature and humidity levels of each habitats was also investigated, which provided us with a better understanding of the ecological preferences and association of these tropical orthopterans.

MATERIALS AND METHODS

Study Sites

Surveys were conducted from December 2022 until March 2023 at ten selected locations across the Klang Valley, Malaysia consisting of five urban habitats (Taman Pudu Ulu, Taman Metropolitan Kepong, Taman Tasik Permaisuri, Taman Alam Damai, Taman Awam Bukit Kiara) and five forested habitats (Sungai Congkak, Bukit Lagong, Sungai Tua, Bukit Gasing, Ulu Gombak). GPS Coordinates of the locations are listed in Table 1. The urban habitats that were selected displayed a combination of artificial and natural features, including mature trees, thriving vegetation, and sometimes the inclusion of man-made lakes. In contrast, the forested habitats showcased flowing rivers that meanders through the rainforest, embellished with rock formations and walking trails.

Table 1. List of locations and their GPS coordinates

No.	Locations	Abbreviation	GPS coordinates
1.	Kuala Lumpur: Cheras, Taman Pudu Ulu	TPU	3.1240 °N, 101.7334 °E
2.	Kuala Lumpur: Kepong, Taman Metropolitan Kepong	TMK	3.2236 °N, 101.6456 °E
3.	Kuala Lumpur: Bandar Tun Razak, Taman Tasik Permaisuri	TTP	3.0958 °N, 101.7199 °E
4.	Kuala Lumpur: Bandar Tun Razak, Taman Alam Damai	TAD	3.0677 °N, 101.7404 °E
5.	Kuala Lumpur: Segambut, Taman Awam Bukit Kiara	TAK	3.1385 °N, 101.6326 °E
6.	Selangor: Hulu Langat, Sungai Congkak	SC	3.2111 °N, 101.8434 °E
7.	Selangor: Selayang, Bukit Lagong	BL	3.2571 °N, 101.6341 °E
8.	Selangor: Batu Caves, Sungai Tua	ST	3.3153 °N, 101.6983 °E
9.	Selangor: Petaling Jaya, Bukit Gasing	BG	3.0968 °N, 101.6588 °E
10.	Selangor: Gombak, Ulu Gombak	UG	3.3261 °N, 101.7573 °E

Insects Sampling and Specimen Preservation

The opportunistic collection was conducted during the daytime between 0800 to 1300 hours as most species of Tetrigidae are the most active during the period (Sperber et al. 2021). Samplings were done by searching for specimens on the ground or riverbank, bushes, under and on the rocks, sifting leaf litter and peeling rotten tree barks. The specimens were collected using universal bottles before preserving in 95% ethanol in 2.0ml microcentrifuge vials. Whenever possible, in-situ photographs of the pygmy grasshoppers were taken using an Olympus OM-D E-M5 Mark II interchangeable lens camera with M.Zuiko Digital ED 60mm F2.8 Macro lens, with the aid of artificial lighting from a torchlight or smartphones. Some of the specimens were later dry-preserved as voucher specimens to be deposited in the Museum of Zoology (MZUM), Universiti Malaya, Kuala Lumpur whereas the rest were remained in ethanol for future molecular studies.

Collection of Environmental Data

The environmental parameters, which are surrounding temperature and relative humidity from each location were recorded for habitat comparisons using RHT3 EzSmart™ Hygro-

Thermometer (EXTECH Instruments, USA). These readings were taken for every individual at the point of collection.

Species Identification

Classification and nomenclature of species were based on the Orthoptera Species File (OSF) Online version 5.0/5.0 (Cigliano et al. 2023) and literature references (Muhammad et al. 2018; Tumbrinck 2019). Species accumulation curve was performed to assess whether a plateau is reached based on the number of species detected in the study areas.

Statistical Analyses

To measure the species composition between urban and forested habitats, distance-based clustering was calculated using Unweighted Pair Group Method with Arithmetic Mean (UPGMA) method based on Jaccard similarity coefficient. The effect of temperature and humidity against the species composition was analysed using Nonmetric multidimensional scaling (NMDS) based on Bray-Curtis dissimilarity index. These statistical analyses were calculated and visualised using the community "vegan" package version 2.6-4 (Oksanen et al. 2022) and "dplyr" version 1.0.10 (Wickham et al. 2022) in R software version 4.2.2 (R Core Team 2022).

RESULTS

Cumulatively, 16 species of Tetrigidae were collected and examined from the 10 selected locations in Klang Valley. The species collected represent the subfamilies Metrodorinae (63%), Scelimininae (6%) and Tetriginae (6%) and tribes Thoradontini (16%) and Criotettigini (9%). In terms of species abundance, this study revealed that *Systolederus cinereus* was the most prevalent (43%) followed by *Bolivaritettix* sp. (18%). Moreover, both species are widely distributed as it was found at most of the studied locations (Table 2).

Table 2. Checklist of Tetrigidae species at the selected urban and forested habitats in the Klang Valley

Subfamily/tribe	Species	Abundance	
		Urban (N=61)	**Forest (N=140)**
Metrodorinae	*Bolivaritettix* sp.	12	23
	Systolederus cinereus	26	60
	Xistrella dohrni	-	4
Tetriginae	*Coptotettix nigrifemurus*	3	2
	Ergatettix interruptus	3	-
	Euparatettix personatus	1	-
	Hedotettix gracilis	3	1
	Lamellitettigodes contractus	-	3
Scelimeninae	*Falconius bedoti*	-	1
	Falconius dubius	-	2
	Scelimena gombakensis	-	9
Criotettigini	*Criotettix bispinosus*	-	19
Thoradontini	*Eucriotettix ridleyi*	-	10
	Eucriotettix simulans	-	2

Loxilobus insidiosus	-	4
Thoradonta nodulosa	13	-

*Taman Alam Damai (TAD), Taman Metropolitan Kepong (TMK), Taman Pudu Ulu (TPU), Taman Awam Bukit Kiara (TAK), Taman Tasik Permaisuri (TTP), Bukit Gasing (BG), Bukit Lagong (BL), Sungai Congkak (SC), Sungai Tua (ST), Ulu Gombak (UG).

Based on this study, *Bolivaritettix* sp. (Figure 1A), *Systolederus cinereus* (Figure 1B), *Coptotettix nigrifemurus* (Figure 1C) and *Hedotettix gracilis* were the only species present in both urban and forested habitats. Three species which are *Ergatettix interruptus*, *Euparatettix personatus* and *Thoradonta nodulosa* (Fig 1D) were only collected from urban habitats, while the rest of the species found in this study (*Criotettix bispinosus*, *Eucriotettix ridleyi*, *Eucriotettix simulans*, *Falconius bedoti*, *Falconius dubius*, *Lamellitettigodes contractus*, *Loxilobus insidiosus*, *Scelimena gombakensis*, and *Xistrella dohrni*) are exclusive to the forested habitats (Figure 2).

Generally, forested habitats possess higher species diversity (H' = 1.35±0.49, N = 13) and abundance (μ = 1.75±1.34) than urban habitats' species diversity (H' = 0.92±0.35, N = 7) and abundance (μ = 0.76±1.83). The species accumulation curves for both habitat types have not obviously plateaued before the last sampling occasion (Figure 3). Although the cumulative species richness of the urban habitats is lower than that of the forested habitats, the slope of the species accumulation curve of the former is lower than that of the latter. This signifies that more sampling effort is imperative to better reflect the Tetrigidae assemblages in both forested and urban habitats.

Figure 1. Some of the pygmy grasshoppers collected in this study: A. *Bolivaritettix* sp.; B. *Systolederus cinereus*; C. *Coptotettix nigrifemurus*; D. *Thoradonta nodulosa*; E. *Xistrella dohrni*; F. *Falconius dubius*; G. *Scelimena gombakensis*; H. *Criotettix bispinosus*; I. *Eucriotettix simulans*

Unweighted Pair Group Method with Arithmetic Mean (UPGMA) dendrogram based on Jaccard similarity coefficient showed distinct clusters between urban and forested habitats in terms of the species composition (Figure 4). Tetrigidae species composition in urban and forested habitats in the Klang Valley was dissimilar as the similarity index values between both habitat types are closer to 0 (J<0.4).

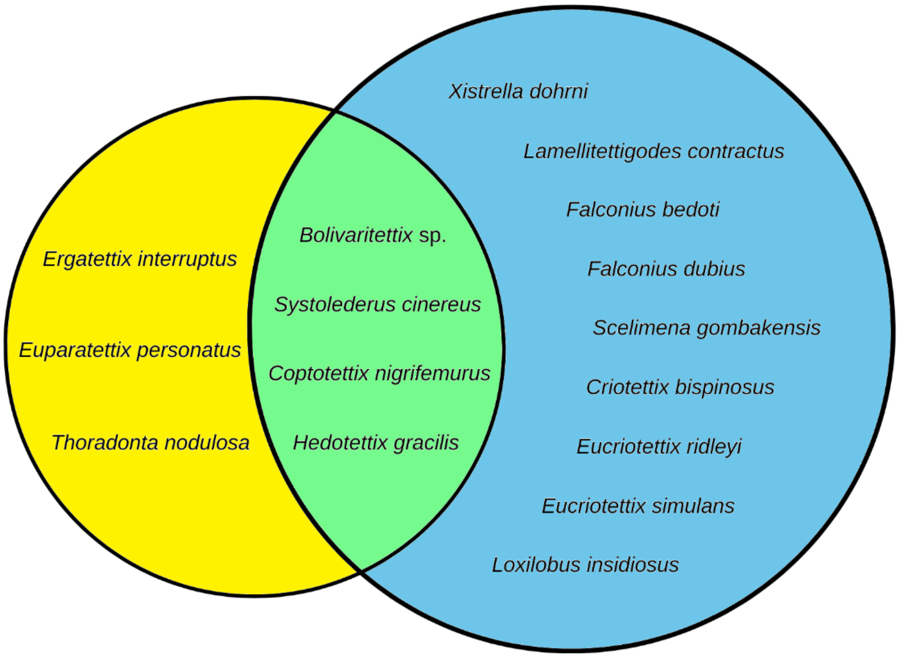

Figure 2. Venn diagram showing the Tetrigidae species with respect to the type of habitat they were present. Yellow represents urban habitats, blue represents forested habitats and green represents both urban and forested habitats

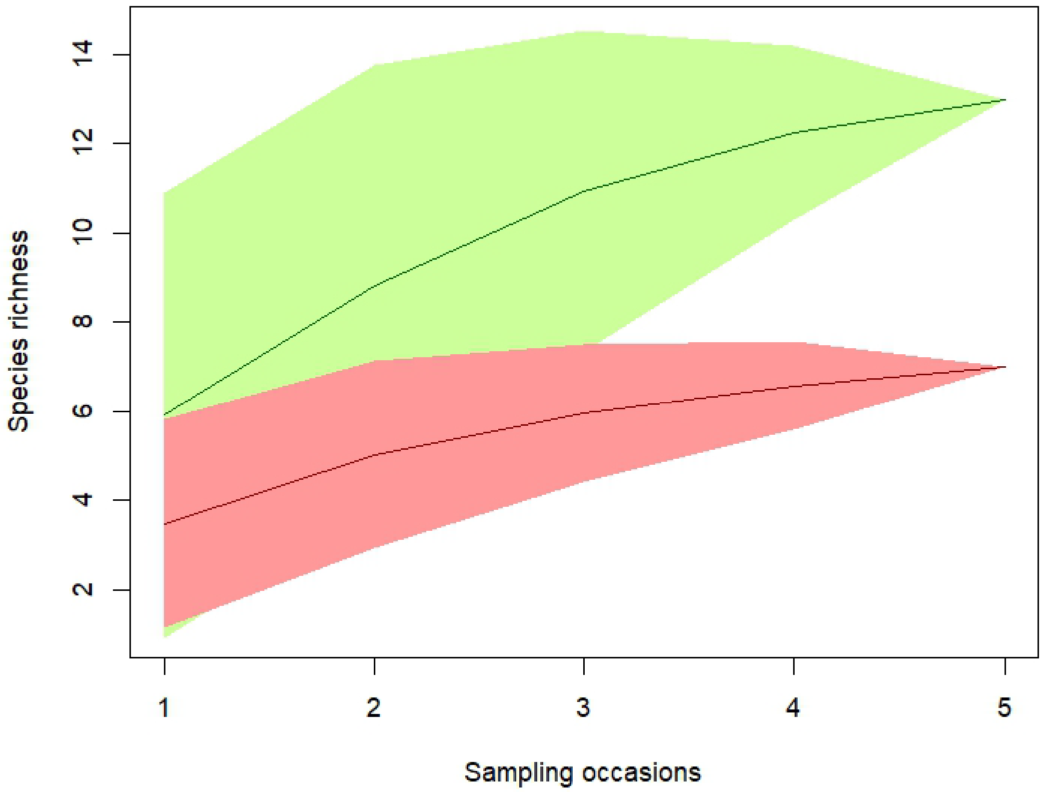

Figure 3. Species accumulation curves of Tetrigidae species collected in the forest (green) and urban (red) areas

The non-overlapping polygons in the non-metric multidimensional scaling (NMDS) plot using Bray-Curtis dissimilarity distance measure illustrates that Tetrigidae species composition between urban or forested habitats differs significantly (t (15) = 2.88, P<0.05) (Figure 4 & 5). This signifies that the Tetrigidae species composition is influenced by cooler and moist conditions of the forested habitats (Temperature: 25.1°C±1.02; humidity: 92.4%±2.07) as compared to the urban habitats (Temperature: 29.14°C±2.17; humidity: 69.6%±10.50).

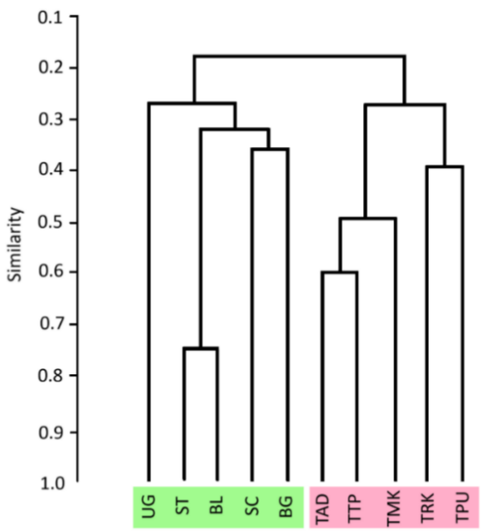

Figure 4. UPGMA dendrogram of the Tetrigidae species at the sampled locations in this study

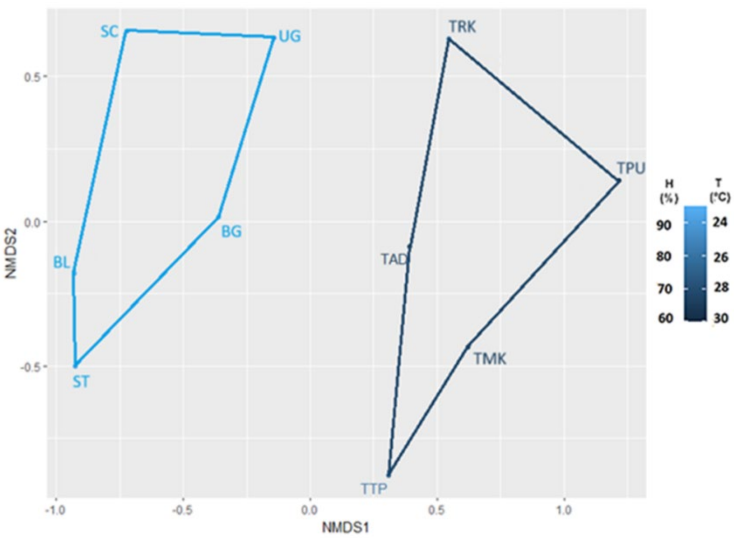

Figure 5. Nonmetric multidimensional scaling (NMDS) plot of Tetrigidae composition based on environmental parameters. Abbreviations: humidity (H), temperature (T), Taman Alam Damai (TAD), Taman Metropolitan Kepong (TMK), Taman Pudu Ulu (TPU), Taman Awam Bukit Kiara (TAK), Taman Tasik Permaisuri (TTP), Bukit Gasing (BG), Bukit Lagong (BL), Sungai Congkak (SC), Sungai Tua (ST), Ulu Gombak (UG)

DISCUSSION

Similar studies involving species composition of insects in disturbed habitats havebeen documented previously both in Peninsular Malaysia (Ng & Nurul Afiqah 2023; Nur-Athirah et al. 2020) and Malaysian Borneo (Abdul Salim et al. 2023). Collectively, the low number of samples in this study may be attributed to the fact that Orthoptera are generally lower in abundance as compared to other insect groups (Nur-Athirah et al. 2020; Nur Syafiqah et al. 2022). For example, the Tetrigidae abundance in Nur-Athirah et al. (2022) constituted only 2.82% of the total insects sampled, despite the use of multiple sampling techniques because the oil palm plantations are subjected to high light intensity and poison (i.e. insecticide) application. Although the total number of Tetrigidae sampled were not specified in the study by Nur Syafiqah et al. (2022), the Orthoptera individual count was less than two percent of total individuals of insects sampled.

In comparison to the urban habitats, the forested habitats harbour more species and abundance of pygmy grasshoppers in this study. Out of 16 species, nine were discovered to be forest-associated. Moreover, the microhabitat associations of these species were specific. This is likely due to the complexity of the forested habitats, i.e., the presence of leaf litter under the forest canopies, abundance of bryophytes and flowing rocky rivers and streams that provide moist substrate and shaded environment. For example, *Scelimena gombakensis*, *Criotettix bispinosus*, *Falconius dubius* and *Falconius bedoti* were collected at or near the flowing rocky rivers. *Lamellitettigodes contractus, Xistrella dohrni* and *Eucriotettix ridleyi* can be found on mossy parts of the trees, logs and rocks close to the rivers; agreeing with the findings of Tan et al. (2017) and Neo et al. (2024). Meanwhile, *Loxilobus insidiosus* and *Eucriotettixsimulans* were collected from the forest ~~floor~~, specifically on the leaf litter and low plant communities. Vegetation composition plays a crucial role not only for Tetrigidae (Nur-Athirah et al. 2022) but also for other insect groups in Malaysia (Abdul Salim et al. 2023; Ng & Nurul Afiqah 2023; Nur Syafiqah et al. 2022).

Changes in the environmental conditions also determines the species diversity and abundance (Christharina et al 2022; Hill et al. 2003). Unlike the forested habitats, the urban areas are highly fragmented and susceptible to environmental fluctuations. Not only are the areas being less complex and isolated, the fewer vegetation cover elevates the temperature and creates the urban heat island effect, which is a threat to pygmy grasshoppers as they are prone to desiccation (Fenoglio et al. 2020; Forsman 2011; Pernat et al. 2024). These factors may jeopardise the pygmy grasshoppers community as their dispersal ability is limited due to their small size and reduced wings (Poniatowski et al. 2020; Steenman et al. 2015). Moreover, the negative impacts are greater towards specialists which rely on specific niches rather than generalists, hence reducing the specialists' species richness and abundance (Ancillotto & Labadessa 2024; Penone et al. 2013).

Members of the tribe Scelimenini (*S. gombakensis*, *F. dubius* and F. *bedoti*) and Criotettigini (*C. bispinosus*) are dependent on the flowing rocky rivers of the forested habitats. Their hydrodynamic body structure such as the elongated pronotum enables them to lead semi-aquatic lifestyle (Muhammad et al. 2023). In Southeast Asia, many Scelimeninae can be found to occupy the riverbanks and forage for submerged food resources (Kuřavová et al. 2017). Although *L. contractus*, *X. dohrni* and *E. ridleyi* have a slender body shape similar to Scelimenini and Criotettigini members, they do not possess special characteristics to adapt for swimming, such as the laterally-compressed first tarsal segments and the serration along the lateral edges of the first tarsal segments and the hind tibiae (Muhammad et al. 2023). Hence, this could be the reason that they are present within the proximity of the rivers but not directly on the water. Furthermore, their ability to camouflage to match the surrounding provides protection from visual detection by predators.

The availability of food resources could also be the key to the flourished abundance and diversity of pygmy grasshoppers in the forested habitats. As their diet consists of algae, bryophytes, fungi and lichen (Hochkirch et al. 2000; Kuřavová & Kočárek 2015; Paranjape et al. 1987), cool and humid conditions is necessary for the survival of pygmy grasshoppers. In the forested habitats, this condition is constantly met and fluctuate less than the urban counterparts, albeit there are concrete structures in the urban parks that support their growth if the conditions are optimal. The presence of flowing water bodies in the forested habitats helps regulate the surrounding temperature and humidity, providing suitable conditions for egg and nymphal development and prevents desiccation (Abdul Salim et al. 2023; Muhammad et al. 2023; Paranjape et al. 1987; Tan et al. 2017). Furthermore, the leaf litter could also hold certain amount of water and acts as a secondary water source for the pygmy grasshoppers. The water contained on the leaf litter could evaporate and stabilize the temperature and humidity within forest environment, creating a suitable microhabitat for pygmy grasshoppers owing to the availability of food resources and egg development (Hochkirch et al. 2000; Kuřavová & Kočárek 2015; Kuřavová et al. 2017).

While the pygmy grasshoppers community flourish in the forested habitats, certain species were resilient in adapting to the challenging dynamics of the urban habitats. The seven species (*Bolivaritettix* sp., *Systolederus cinereus*, *Coptotettix nigrifemurus*, *Hedotettix gracilis*, *Ergatettix interruptus*, *Euparatettix personatus* and *Thoradonta nodulosa*) found in the urban environments in this study displayed a higher tolerance to the fluctuating temperature and humidity. The vegetation such as shrubs and few tree clusters in the urban habitats creates shade and moisture retention, offering suitable environmental conditions and provides a refuge to these species (Armson et al. 2012; Cameron et al. 2012; Cregg & Dix 2001). Artificial structures such as concrete that create niches in the urban habitats were also utilised by these species as an adaptation for survival (Neo et al. 2024). The sufficiently lowered pH, microstructure and surface roughness of concrete structures may become hospitable to bryophyte growth (Westhoff 2020). Since most mosses are poikilohydric and have low water and nutrient requirements, the porous characteristic of concrete traps adequate amount of water needed by mosses (Anderson et al. 2010; Vanderpoorten & Goffinet 2009).

Lastly, this study is not without its limitations namely limited study duration and weather condition. The data may be inaccurate since this project was short termed. Moreover, the weather condition during the sampling period was unpredictable, with more rainy days as compared to the sunny ones. The weather condition did not permit extensive and thorough sampling as our sampling period was unwillingly shortened and limited our access to certain parts of the sampling areas due to the rise in water level of the rivers. This indicates that further sampling should be made and more parameters need to be considered.

CONCLUSIONS

Based on these findings, some species of pygmy grasshopper may occupy both urban and forested habitats, albeit others are more restricted to one type of habitat. Nevertheless, the forested habitats harbour more species than urban habitats and both habitats combined, signifying the importance of preserving and conserving such habitat as a reservoir for this overlooked taxon. Even though the urban habitats pose some limitations as compared to the forested counterpart, they still have the potential to contain certain pygmy grasshopper species, given their necessities are met. Further research is warranted to examine other factors that would influence the distribution of pygmy grasshoppers in the Klang Valley. Increasing the sampling efforts and extending similar studies into other ecosystems is necessary to provide information for better management of rapidly urbanising habitats.

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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.

Authors' Contributions

Nurul Ashikin Abdullah (NAA) and Amira Aqilah Muhammad (AAM) conceptualised this research; Norfatihah Aisyah Abd Rahim (NAAR) and AAM carried out fieldworks; NAAR, AAM and NAA participated in the design and interpretation of the data; NAAR and AAM wrote the paper; NAA participated in the revisions of it. All authors read and approved the manuscript. All photographs used in this manuscript are owned by AAM.

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