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Diversity of Orthoptera at Bukit Ulu Piah, Tambun, Perak, Peninsular Malaysia

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Abstract: Orthoptera plays an important role in maintaining the ecosystem and is diversely distributed, with over 29,100 described species worldwide. Bukit Ulu Piah, Tambun, or Perak have ever reported no such description. This study was conducted to identify the diversity of Orthoptera and provide the first Orthoptera species checklist of the area. Net-sweeping sampling was conducted from January to April 2022 (S1, S2, S3, and S4), between 0900 and 1700. The species abundance data were analyzed using PAST software to determine the Shannon diversity index (H'), Margalef index (D_{mg}), and Evenness index (E). A total of 508 specimens from six families—Acrididae, Pyrogomorphidae, Chorotypidae, Tetrigidae, Gryllidae, and Tettigoniidae—were successfully recorded, with Acrididae showing the highest percentage value of 39.5% (15 species). Species composition comprised 38 species in 32 genera within two suborders: Caelifera (21 species) and Ensifera (17 species). *Melanoplus* sp. was the most common and abundant species, with 59 individuals (11.6% of total specimens). Orthoptera diversity in Bukit Ulu Piah, Tambun recorded high diversity (H'= 3.037), high species richness (D_{mg} = 5.939), and uniform species evenness (E = 0.5487). There was no significant difference (F = 0.4316, df=3, p > 0.05) in the abundance of Orthoptera across the sampling area, though this study was conducted over a short period. While this checklist provides preliminary information on Orthoptera in this area, a more extensive study should be conducted for a better assessment of its ecological status.

Keywords: *Diversity, Orthoptera, ecosystem, species richness, Bukit Ulu Piah.*

1. Introduction

Orthoptera are insects that have existed since 300 million years ago, during the Carboniferous period (Siedle et al. 2016). To date, it is estimated that over 29,100 species have been identified worldwide, covering all terrestrial ecosystems except the Antarctic continent (Cigliano et al. 2021; Ingrisch & Rentz 2009; Tan & Kamaruddin 2016a). The diversity of Orthoptera is high in tropical areas because it is the most favorable habitat for development and survival compared to other ecosystems (Sperber et al. 2021). As such, more than 2,000 Orthoptera species have been described from tropical Southeast Asia (Tan 2017). Orthoptera is the sixth largest order, consisting of suborder Caelifera (grasshoppers) and Ensiferea (katydids and crickets) (Ingrisch & Rentz 2009). The length of the antennae and the position of the tympanum membrane on the body structure are morphological features that are frequently used in Orthoptera species identification and classification. Caelifera has short antennae (less than 30 segments), and the tympanum membrane (if present) is found in the first abdominal segment, whereas Ensifera has long antennae (more than 100 segments) that resemble hair, and the tympanum membrane (if present) is found in the front tibia (Song 2018).

Orthoptera was first described in Malaysia in 1875 (Stål 1875), and studies in several localities in Peninsular Malaysia have resulted in the discovery of numerous new species such as *Lichnofugia malaya* (Tan & Ingrisch 2014), *Hancockitettix humeratus* (Storozhenko & Pushkar 2017), and *Gryllotalpa permai* (Tan & Kamaruddin 2016b). The more recent records of new species of Orthoptera include *Cycloptiloides bimaculata* (Tan et al. 2021) and *Varitrella (Cantotrella) suikes* sp. nov (Tan et al. 2020) found in Borneo. Generally, the documentation of Orthoptera started long ago, though it remains incomplete. While various studies have been done to record the Orthoptera in Peninsular Malaysia, this has yet to be done in Bukit Ulu Piah, Tambun, Perak.

The presence of Orthoptera is significant to vegetation as it signifies the ecosystem's health. The Orthoptera are important herbivores, becoming a nutritional food source for other predatory animals while also being predators of other smaller

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insects (Tan & Kamaruddin 2016a). Due to their high sensitivity to ecological changes, Orthoptera can potentially serve as a biological indicator in an ecosystem (Fartmann et al. 2012). For example, *Spathosternum prasifernum prasifernum* is one of the Orthopteran species with bioindicator potential for pesticide use (Manna et al. 2020). The absence or extinction of Orthoptera species has been shown to disrupt the stability of the trophic layer structure in an ecosystem (Song 2018; Ngoute et al. 2020). Apart from that, Orthoptera possess economic significance as plant pests that invade from one area to another as a result of high population density (Song 2018). The locusts of the family Acrididae, for instance, were found in high abundance in land cleared for rice, as they feed on the initial growth of grasses. Nevertheless, the locusts are not considered significant rice pests with the appropriate management of the rice field (Le Gall et al. 2019).

Bukit Ulu Piah is a lowland secondary dipterocarp forest hill in the Kinta district, Perak. In early 1917, a tin mine was located on this forested hill (Khoo Salam & Abdur-Razak 2005). As the mining area was closed, most of the areas were converted into smallholder plantations and agricultural areas (Loh 2021). While this hill is nestled against a limestone landscape, most research activities have been focused on the limestone areas. This has led to limited information on the impact of forest clearing for agricultural purposes on the diversity of fauna communities in this area, including the Orthoptera. In order to address the knowledge gaps, this study is conducted with the objectives: 1) to provide a preliminary checklist of Orthoptera species found in Bukit Ulu Piah, and 2) to determine the diversity, richness, and abundance of Orthoptera in the area. This can provide an overview of the ecological status of each Orthopteran species in the area. This preliminary information can be considered the first step toward conserving and preserving the national ecosystem by 2025, fitting with the goals of the Malaysian National Biodiversity Policy.

2. Experimental Methods

Sampling Site

Samples were collected at Bukit Ulu Piah, Tambun, Perak. Bukit Ulu Piah is a lowland, secondary dipterocarp forest in the Kinta district, Perak, situated at 4° 35' 59" N, 101° 09' 59" E. The highest peak of Bukit Ulu Piah stands at an altitude of 175m above sea level. The sampling site comprised vegetated areas, including grasslands, fenced plants, understory vegetation in palm oil tree areas, and slopes covered with shrubs, saplings, tall trees and grass on both sides of the vehicle path to the hill summit.

Sampling Method

Sampling was conducted over four consecutive months: January (S1), February (S2), March (S3), and April (S4) at random times between 0900 and 1700 on each sampling occasion. Each sampling period consisted of two consecutive days during the second week of each month. Active sampling was performed opportunistically by walking along roads and trails of the hill forest (Tan & Kamaruddin 2016b). The sampling involved opportunistic collections through visual observation of plants, fallen trees, leaf litter, and sweeping vegetation using a sweep net measuring 30 cm in length and 25 cm in width.

Laboratory work

All collected specimens were placed in killing bottles containing ethyl acetate vapor to eliminate the insects. The specimens were subsequently preserved and identified before storage in insect boxes. A size-3 insect pin was used to pin Orthoptera specimens through the right side of their pronotum. When pinning grasshopper specimens, the hind wings were stretched to display their distinctive color and wing veining (Triplehorn & Johnson, 2005). Following the pinning procedure, specimens were oven-dried for preservation (Mohamad Salleh 1983). The preserved specimens were then labeled with collection date, location, and collector's name. Specimen identification was conducted primarily by morphospecies using references such as Triplehorn and Johnson (2005), Tan and Kamaruddin (2014, 2016a), Siedle et al. (2016), and Tan (2017). For identification and classification, applications like Picture Insect—Insect ID Pro and websites including Orthoptera Species File Version 19 5.0, Malaysia Biodiversity Information System (MyBIS), and The Biodiversity of Singapore were utilized.

Data Analysis

Species abundance refers to the high number of individuals in a species in comparison to other species. A large number of individuals obtained in the field makes the species dominant. Common species is referred to as the frequency of a species found relative to the number of samplings done at the study location and overall. Therefore, the identified common species have the potential to become abundant, and abundant species are also known as dominant species. One-way ANOVA was conducted to test significant differences in the abundance of Orthoptera in different sampling occasions. Shannon's Diversity Index (H'), Margalef's Index (D_{mg}), and Shannon's Species Evenness Index (E) were used to calculate diversity, species richness, and species evenness, respectively. T-test was conducted as a post-hoc test to determine the significant differences between the diversity value of each sampling occasion. Accumulation curves were generated using the Chao-1 richness estimator (Chao et al. 2020). All statistical analyses were conducted using PAST v4.04 (Hammer & Harper 2001).

3. Results and Discussion

Samplings of Orthoptera were conducted in Bukit Ulu Piah Tambun, Piah, to identify the diversity and abundance of Orthoptera based on samplings in January (S1), February (S2), March (S3), and April (S4). All sampling occasions recorded a total of 508 individuals representing six families and 38 species (Table 1). Out of the 38 species, 21 species are represented by four families (Acrididae, Pyrogomorphidae, Chorotypidae, and Tetrigidae) in suborder Caelifera, while the other 17 species are represented by two families (Gryllidae and Tettigoniidae) in suborder Ensifera. The Acrididae and Tettigoniidae are the most

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speciose groups, respectively, with *Melanoplus sp.* (Acrididae) identified as the most common and abundant species in Bukit Ulu Piah, with 59 individuals recorded in the four months of sampling.

The overall orthopteran diversity in Bukit Ulu Piah is H'= 3.037, while S2 has the highest diversity (H'= 2.900) of Orthoptera compared to S3 (H'= 2.763), S1 (H'= 2.665), and S4 (H'= 2.608). The difference among groups calculated showed no significant difference ($F = 0.4316$, $df=3$, $p > 0.05$). However, the post-hoc t-test on H' value shows a significant difference between S1 and S2 ($t= 2.314$, $df=1$, $p < 0.05$) and between S2 and S4 ($t= 2.743$, $df=1$, $p < 0.05$). Species richness is highest in S2 (Dmg = 5.538), followed by S3 (Dmg = 4.684), S4 (Dmg = 4.662), and S1 (Dmg = 4.372). The species evenness index (E= 0.5487) almost approaches unity 1.0, indicating nearly uniform species evenness. Chao-1 estimated 23 species for S1, 31 species for S2, and 35 species for S3 and S4. The estimated richness is very close to the observed richness (Table 2).

The accumulation of samples is shown on species-based rarefaction curves over the species richness for the entire sampling of Orthoptera at Bukit Ulu Piah, Tambun, Perak. The graph showed that sampling at these areas has approached but not reached the asymptote (Figure 2). This indicates that four sampling occasions are still insufficient to describe the entire diversity of Orthoptera in Bukit Ulu Piah, Tambun, Perak.

Table 1. Preliminary checklist and abundance of Orthoptera in Bukit Ulu Piah, Tambun, Perak collected from January 2022 (S1) to April 2022 (S4)

Suborder and Family	Species	S1	S2	S3	S4
Suborder Caelifera Acrididae	*Acrida conica* (Fabricius, 1781)	0	2	1	3
	Apalacris varicornis Walker, 1870	0	4	1	1
	Gesonula mundata (Walker, 1870)	0	1	0	0
	Melanoplus sp.	13	13	29	4
	Oxya intricata (Stål, 1861)	2	0	0	0
	Phlaeoba antennata Brunner von Wattenwyl, 1893	9	7	5	18
	Phlaeoba antennata malayensis Bolívar, 1914	0	4	4	0
	Phlaeoba infumata Brunner von Wattenwyl, 1893	11	12	15	18
	Phlaeoba sp.	12	11	14	0
	Pseudoxya diminuta (Walker, 1817)	10	17	18	3
	Pternoscirta caliginosa (Haan, 1842)	2	0	1	0
	Stenocatantops splendens (Thunberg, 1815)	0	0	0	1
	Trilophidia annulata (Thunberg, 1815)	3	4	1	3
	Valanga nigricornis (Burmeister, 1838)	1	2	3	1
	Xenocatantops humilis (Serville, 1838)	0	3	3	0
Pyrogomorphidae	*Atractomorpha* cf. *psittacina* (Haan, 1842)	0	4	6	16
	Tagasta marginella (Thunberg, 1815)	6	16	15	3
Chorotypidae	*Erianthus* sp.	0	0	0	1
Tetrigidae	*Bolivaritettix* sp.	0	1	2	0

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	Coptotettix sp	2	0	1	0
	Macromotettix sp	1	1	0	1
Suborder Ensifera Gryllidae	*Euscyrtus (Osus) concinnus* (Haan, 1844)	0	2	0	2
	Loxoblemmus parabolicus Saussure, 1877	2	1	0	12
	Nisitrus vittatus (Haan, 1844)	1	2	1	1
	Patiscus cf. brevipennis Chopard, 1969	0	0	1	0
	Teleogryllus (Teleogryllus) albipalpus He, 2018	0	1	0	1
	Velarifictorus (Velarifictorus) micado (Saussure, 1877)	0	2	4	1
	Velarifictorus (Velarifictorus) aspersus (Walker, 1869)	1	2	4	0
Tettigoniidae	*Cesasundana lorniensis* Tan, 2014	0	0	3	10
	Conocephalus (Anisoptera) maculatus (Le Guillou, 1841)	9	9	14	5
	Conocephalus (Anisoptera) melaenus (Haan, 1843)	0	0	4	1
	Euconocephalus sp.	0	1	9	4
	Hexacentrus unicolor Serville, 1831	2	1	9	2
	Mecopoda elongata (Linnaeus, 1758)	1	0	0	0
	Phaneroptera brevis Serville, 1838	2	0	0	0
	Phaneroptera falcata (Poda, 1761)	0	5	0	0
	Phaulula macilenta Ichikawa, 2004	1	2	0	0
	Ruspolia lineosa (Walker, 1869)	6	1	0	0
	Sub-Total	97	131	168	112
	TOTAL	508			

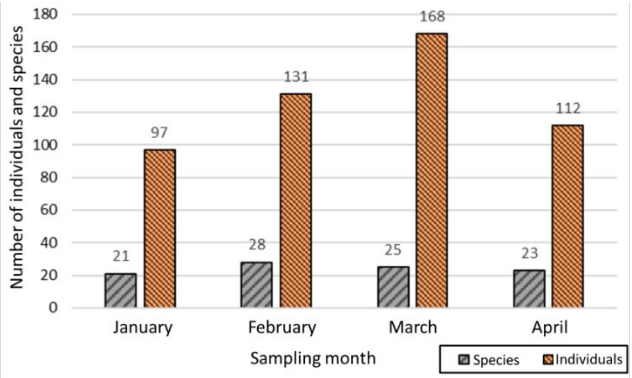

Figure 1. Species composition according to samplings months.

Table 2. Species diversity indices of the orthoptera based on four sampling occasions from January 2022 (S1) to April 2022 (S4)

	S1	S2	S3	S4
Taxa	21	28	25	23
Individuals	97	131	168	112
Margalef, D_{mg}	4.372	5.538	4.684	4.662
Shannon, H'	2.665*	2.900*	2.763	2.608*
Evenness	0.6843	0.6494	0.6340	0.5902
Chao-1	23	31	35	35

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***Significant differences shown between S1 and S2, S2 and S4 at P<0.05)**

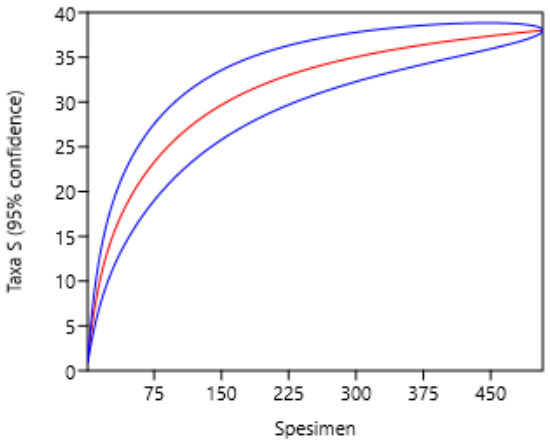

Figure 2. Rarefaction-based accumulation curve indicating the number of species relative to the number of individuals captured throughout the study.

Discussion

Orthoptera is a diverse order with a worldwide distribution. Suborder Caelifera was found in higher abundance than Ensifera, as Caelifera is biologically active during the day, which fits with the sampling period of this study. The active period of grasshoppers starts when the sun rises to enhance their metabolism and boost their foraging and sexual searching activities (Kistner & Belovsky 2017). Therefore, the Caelifera forages for food by locating suitable plant hosts during hot and sunny days. On the other hand, the ensiferans are primarily nocturnal, copulating and foraging during the night (Tan 2019). As the sampling conducted was limited to daytime, a low number of Ensifera were collected in Bukit Ulu Piah, Tambun, and Perak. Future studies should consider collecting the samples both day and night to account for diurnally and nocturnally active species.

Acrididae have been recorded as the most abundant family in Bukit Ulu Piah, dominated by *Melanoplus* sp., a generalist feeder with high habitat adaptability (Schmitz et al. 2015). Other studies have also reported a large species composition of Acrididae, with 8000 identified species belonging to 1500 genera and 25 subfamilies in the world (Shah et al. 2018). The majority of Acrididae are herbivorous and feed on different types of plants depending on hunger levels and dampness of food sources, though most of the grasshoppers have host preferences (Song et al. 2018). Bukit Ulu Piah was also observed to have a diversity of plant species as an ideal food source for the Acrididae, amplifying its abundance and diversity, as also shown in Threllfall et al. (2017).

The Shannon Diversity Index (H') of Orthoptera in Bukit Ulu Piah is shown to vary between sampling months (S1, S2, S3, and S4). This is due to the fluctuating number of species each month with regard to its growth cycle and breeding phase, which is also influenced by the egg-hatching period of the Orthoptera (Zergoun et al. 2018). The overall diversity index of Orthoptera in Bukit Ulu Piah is H'= 3.037. However, there is no comparable value, as the diversity data of Orthoptera in Malaysia is dispersed through many different sampling methods and measurements. A standardized monitoring practice for Orthoptera will be much needed for a better status analysis of this order in the region.

Nevertheless, a comparison can be made based on the number of families. The number of Orthoptera families sampled in Bukit Ulu Piah, Tambun, was lowest when compared with Bukit Larut, Perak (10 families) (Tan & Kamaruddin 2016a) and Bukit Fraser, Pahang (10 families) (Tan & Kamaruddin 2014). Four families recorded in Bukit Larut and Bukit Fraser were not found in Bukit Ulu Piah. The four absent families in Bukit Ulu Piah are Trigonopterygidae, Gryllacrididae, Gryllotalpidae, and Mogoplistidae. While this study was done in a short period with an accumulation curve that did not reach an asymptote, it is still important to note that the difference in the type of family found might also be caused by geographical variations and the type of habitats. Bukit Larut and Bukit Fraser are highlands with altitudes of more than 1000m above sea level, in comparison with Bukit Ulu Piah, a lowland dipterocarp forest with the highest altitude at only 175m above sea level. Based on this information, it is hypothesized that Trigonopterygidae, Gryllacrididae, Gryllotalpidae, and Mogoplistidae have better adaptations to survive in higher altitudes, though this should be further explored. The absence of the four Orthopteran families may also be caused by the nature of Bukit Ulu Piah as a secondary forest, which has been disturbed by mining activities.

The fluctuating pattern was also shown in the number of Orthoptera individuals, as it peaked in March 2022. The populations are known to be highly influenced by temperature, where they are more active in locomotion for foraging and breeding in higher temperatures. This coincides with March 2022 being the drier season, with lower rain distribution following the final phase of the northeast monsoon. This occurred primarily in the northern region of Peninsular Malaysia, where Bukit Ulu Piah is located. The northern weather station in Chuping recorded a maximum temperature of 34–35 °C in March 2022 (Halid 2022). A study done by Prinster et al. (2020) also recorded an increased number of individuals during the summer or in July, which declined by September, indicating the pivotal role of temperature in determining the distribution of Orthoptera. This suggests that a more thorough study should be conducted to determine any significant correlation between Orthoptera and the abiotic factors of Bukit Ulu Piah.

A species of significant importance, namely *Valanga nigricornis* (n=7), has been recorded in Bukit Ulu Piah. Apart from corn (Prakoso 2017) and sugarcane (Sarjan et al. 2023), this species has been reported to cause severe outbreaks in young oil palm, rubber, and cocoa in the 1980s (Oktafanda 2022). The nymph of V. nigricornis actively feeds in between leaf veins, while the adult feeds on all the leaves. While it has yet to be reported to cause severe infestation in recent years, it is crucial for monitoring to be done continuously in order to assess its status, especially when Bukit Ulu Piah is currently surrounded by multiple agricultural

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plantations, including rubber, durian, as well as cash crops such as corn.

4. Conclusion

The diversity of Orthoptera at Bukit Ulu Piah, Tambun, Perak, resulted in 38 species dominated by the Suborder Celifera with a high number of Acrididae. The results suggested that a secondary forest such as Bukit Ulu Piah may still hold rich biodiversity despite the disturbance that occured. This study indicates that further intensive sampling needs to be carried out to account for Orthoptera of all ecological strata for a more accurate diversity measurement. In anticipation of growing agricultural areas in Bukit Ulu Piah, a continuous monitoring is also suggested to be done to determine the impact of such activities on the Orthopteran community. It is also important to note that the diversity of Orthoptera in Malaysia remains non-exhaustive, with more new records and species to discover.

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