Jurnal Pijar MIPA
https://jurnalfkip.unram.ac.id/index.php/JPM
ISSN 1907-1744 (Print)
ISSN 2460-1500 (Online)

Diversity of Grasshopper (Hexapoda: Orthoptera) in the Conservation Area of Kerandangan Natur Park, Senggigi, West Lombok

Mohammad Liwa Ilhamdi[1]*, Muhammad Syazali[2], Baiq Febrian Sari Rizki[2]

[1]Biology Education Department, University of Mataram, Mataram, Indonesia
[2]Elementary School Teacher Education, University of Mataram, Mataram, Indonesia
*E-mail: liwa_ilhamdi@unram.ac.id

Received: February 17, 2024. Accepted: March 28, 2024. Published: March 30, 2024

Abstract: The Kerandangan TWA conservation area has high biodiversity, but much of it is unknown, including grasshoppers. This research aims to analyze the diversity of grasshoppers in the area. Grasshopper samples were collected on two transects determined purposively. This collection was carried out over two months, namely October to November 2022. Data on species and numbers were analyzed descriptively. This analysis includes abundance, richness index, diversity index, and species evenness index. Our findings show that there are 8 species of grasshoppers from the families Acrididae, Pyrgomorphidae, Catantopidae, and Tettigoniidae. The most abundant species was *Stenocatantops splendens*, whose proportion was 66.67%. The species richness, diversity, and evenness indexes were 2.06, 1.27, and 0.61, respectively. This shows that grasshopper biodiversity in Kerandangan TWA is relatively low. However, it must be conserved because of its essential role in maintaining regional ecological processes.

Keywords: Conservation Area; Grasshoppers; Kerandangan Nature Park.

Introduction

Kerandangan Nature Tourism Park is a nature reserve located in Senggigi Preparation village, Batu Layar sub-district, West Lombok district [1]. This park has an area of 396.10 hectares and is part of the Senggigi Tourism Village area in West Lombok district [2]. The exploration route in the Kerandangan Nature Tourism Park is a combination of paving and dirt paths [3]. This park offers a peaceful natural atmosphere; visitors can walk along paths under the shade of tall, shady trees accompanied by heavenly natural songs. This park is home to several species of birds, some of which are endangered, such as the Flore Eagle (Nisaetus floris). Visitors can enjoy bird-watching activities in the wild or natural bird habitats. The park also has waterfalls, including Putri Kembar waterfall and Swallow Cave, located on marked trails. The park is an ideal place to escape the tourist hustle and bustle of Senggigi and enjoy a few hours' walk in the rainforest [4]. Various types of plants in TWA Kerandangan function as producers for many kinds of first-order consumers. One of them is the grasshopper.

Grasshoppers are essential to many ecosystems and play an important role in food webs. They are herbivorous animals and consume large amounts of plant biomass, which can affect the biomass of plant communities [5]. Grasshoppers are also important prey for many animals, including birds, reptiles, and mammals [6]. Additionally, grasshoppers can be destructive pests, and their outbreaks can damage crops and livestock [7]. The importance of grasshoppers in a habitat depends on various factors, including their abundance, species composition, and interactions with other organisms in the ecosystem.

Grasshoppers can positively and negatively impact plant growth and soil health. As herbivores, they consume large amounts of plant biomass, which can affect the biomass of plant communities [8]. However, one study found that grasshopper herbivory had a more substantial and consistent impact on native plant restoration than invasive grasses. Locusts can also affect root morphology, making roots thinner with an increase in specific root length and area and a decrease in root tissue density compared to untreated control plants [9]. Grasshoppers can be destructive pests and outbreaks that can damage crops and livestock. Ash from volcanic eruptions, which can be lethal to certain insects such as grasshoppers, can also reduce water infiltration, increase surface albedo, and affect water runoff, erosion, evaporation, and soil temperature even when worked into the soil [10]. Overall, the impact of grasshoppers on plant growth and soil health depends on various factors, including their abundance, species composition, and interactions with other organisms in the ecosystem.

The critical role of grasshoppers in preserving the ecosystem is not directly proportional to conservation efforts in their habitat. This is due to the lack of information regarding the grasshopper group itself. On Lombok Island, only 2 studies have explored information about these animals. These two studies were conducted in vegetable fields in the Lingsar area, West Lombok [11],

How to Cite:
Ilhamdi, M. L., Syazali, M., & Rizki, B. F. S. (2024). Diversity of Grasshopper (Hexapoda: Orthoptera) in the Conservation Area of Kerandangan Natur Park, Senggigi, West Lombok. *Jurnal Pijar Mipa*, *19*(2). https://doi.org/10.29303/jpm.v19i2.6593

and the rice field ecosystem in Beriri Jarak village, East Lombok [12]. There are two research reports Outside Lombok Island, which is administratively the same province as West Nusa Tenggara. Both were carried out in agricultural and savanna habitats on Sumbawa Island, precisely in the administrative area of the Dompu district [13]. In the Kerandangan TWA area, grasshoppers' presence was confirmed in only one study. This research does not explicitly have a study object for grasshoppers but is related to the diversity of soil insects [14]. In this research, we specifically studied the grasshopper community in Kerandangan, TWA. This research aims to analyze the diversity of grasshopper species. Scientific products from the results of this research can be used for regional conservation management purposes.

Research Methods

This exploratory, descriptive research was conducted in the TWA Kerandangan area in Senggigi village, Batu Layar sub-district, West Lombok (Figure 1). Field data was collected at the interval from October to November 2022. Grasshopper samples were collected on two transects in the middle of the Kerandangan TWA forest. Searches for grasshoppers were carried out along the transect and areas on either side of the transect for a minimum distance of 10 meters. Every grasshopper found was photographed for documentation and captured using an insect net. Each species that is collected is placed in a clear plastic bag. One clear plastic bag for 1 individual grasshopper specimen. To ensure that the grasshopper specimens are preserved, we inject 7% alcohol or 4% formalin into the cephalopods, thorax, and abdomen. Each specimen is identified to the species taxon. We used the identification book from Tan and Iorio [15-17] and several articles published in journals such as Suranadi and Dompu [11-13]. In addition to species data, we recorded the number of each species identified.

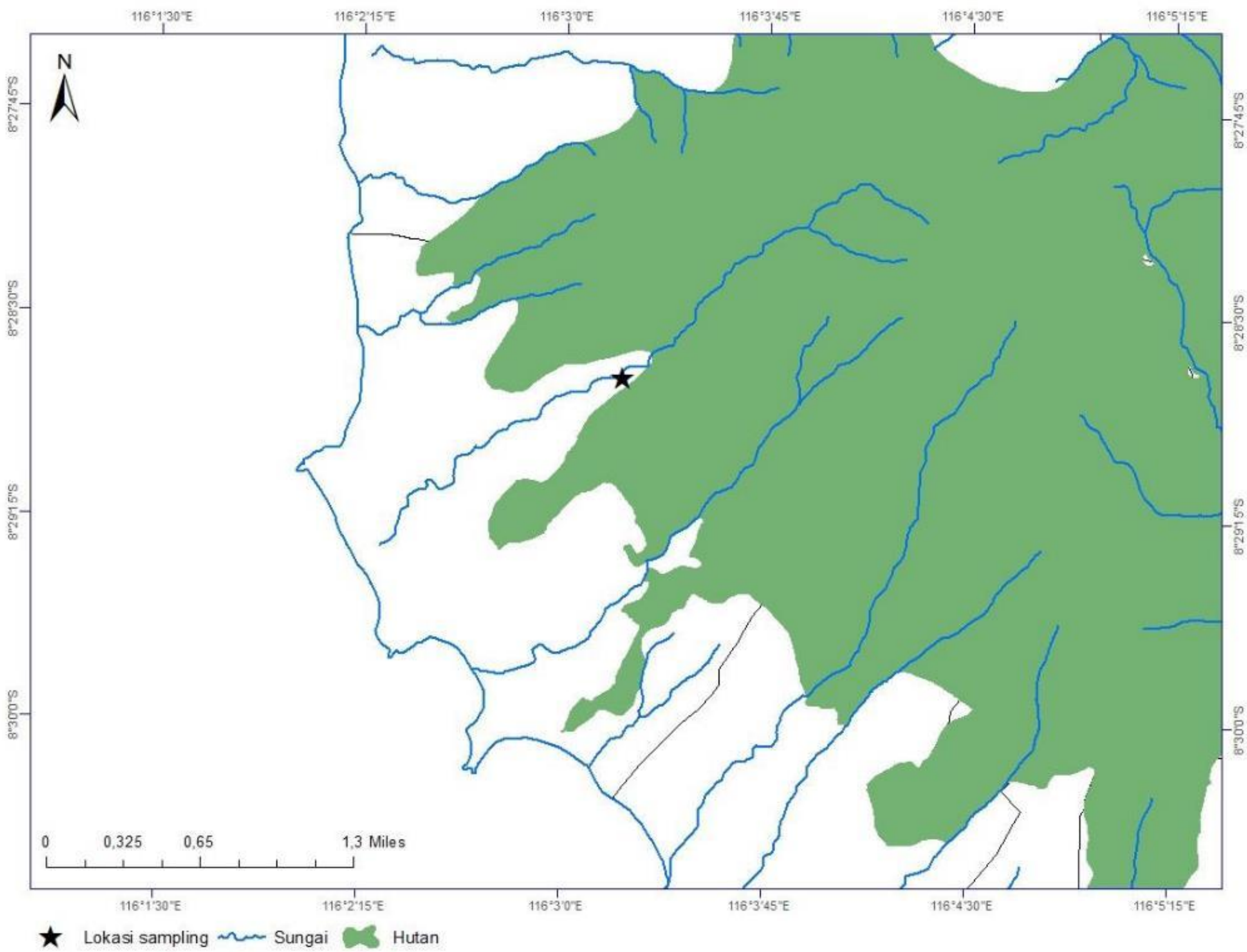

Figure 1. Map of research location

The species and number data were then analyzed descriptively with the help of Microsoft Excel. The ecological variables analyzed include relative abundance, richness index, diversity index, and species evenness index. Relative abundance refers to the equation used by Ilhamdi [11]. Mathematically, the equation is $Kr = \frac{n_i}{N} \times 100\%$. Where Kr is the relative abundance (%), n_i is the number of individuals of species I, and N is the number of individuals of all species. The species richness index refers to the formula from Margalef [18]. Mathematically, the equation is$R = \frac{S-1}{ln ln\, N}$. The diversity index was measured using the Shannon-Wiener equation [19]. Mathematically, the equation is$H' = -\sum p_i\, ln\, ln\, p_i$. Where H' is the Shannon-Wiener diversity index, and p_i is the ratio between the number of individuals of species i and the number of individuals of the entire species. The diversity index calculation uses the index from Slovin [20]. Mathematically, the equation is$E = \frac{H'}{ln ln\, S}$. Where E is the species evenness index, H' is the Shannon-Wiener diversity index, and S is the number of species. Diversity data from the analysis results were visualized as a bar chart using Microsoft Excel.

Results and Discussion

Research carried out at the Kerandangan Nature Tourism Park (TWA) through two transects found 30 individuals from several species of the Orthoptera order. The total number of species identified is 8 species from 4 different families. Photographs of several species can be seen in Figure 2. One species represents the Pyrgomorphidae family, one species represents the Catantopidae family, one species represents the Tettigoniidae family, and five species represent the Acrididae family (Table 1). The number of species from the Orthoptera order found in the Kerandangan Nature Tourism Park (TWA) area is lower than those found in other places. For example, in Hamlet III, Rambah Hilir Tengah Village, Rambah Hilir District, Rokan Hulu Regency, there are 16 species originating from 2 different families, namely Gryllidae and Tettigoniidae [21] and in the Suranadi Nature Tourism Park (TWA) 11 species were found originating from 3 different families, namely Acrididae, Pyrgomorphidae, and Tettigoniidae [22]. However, when compared with the findings in the Baturaden Botanical Gardens, Banyumas, there are 7 species of the Orthoptera order that belong to 3 different families, namely Tetrigidae, Acrididae and Pyrgomorphidae [23]. The number of species found in TWA Kerandangan is relatively higher. If we look at the number of families, the families found in TWA Kerandangan are higher than the families found in other places, namely 4 families consisting of Pyrgomorphidae, Catantopidae, Acrididae, and Tettigoniidae.

Picture 2. Locust photographer at TWA Kerandangan

Table 1. Composition of grasshopper species found in Kerandangan TWA

No	Family	Species	N (individual)	Proportion (%)
1	Pyrgomorphidae	*Atractomorpha crenulata*	2	6.67
2	Catantopidae	*Stenocatantops splendens*	20	66.67
3	Acrididae	*Phlaeoba antennata*	2	6.67
4	Acrididae	*Oxya hylaintricata*	1	3.33
5	Acrididae	*Dissosteira carolina*	1	3.33
6	Acrididae	*Chorthippus Brunneus*	1	3.33
7	Acrididae	*Nigrocorni avalanche*	2	6.67
8	Tettigoniidae	*Phaneropterinae sp*	1	3.33
		Jumlah (Σ)	30	100

Table 1 shows that the family with the most species is Acrididae, with a total of 5 species, while the other families are only represented by 1 species each. Based on the research results, what factors cause the Acrididae family to have a greater number of species than other families is not yet known. However, the research results provide information on the diversity and distribution of Acrididae species in various habitats and ecosystems. The high number of Acrididae species in a habitat or ecosystem can be influenced by factors such as topography, climate, vegetation, and other biotic and abiotic factors [24]. In addition, genetic factors such as gene duplication and loss and the number and location of multigene families may also play a role in variations in gene content and evolutionary rates between species [25-26]. However, how these genetic factors relate to the high species diversity in the Acrididae family is unclear.

Based on research results, several adaptations of the Acrididae family may contribute to the high diversity of species. One of their adaptations is their ability to feed on a wide variety of plant species, allowing them to occupy various habitats and ecosystems. Another adaptation is the ability to undergo morphological and physiological changes in response to environmental conditions, such as temperature, humidity, and food availability. In addition, some species of Acrididae have developed specialized structures and behaviors for defense against predators, such as spines, camouflage, and jumping ability. These adaptations may have allowed the Acrididae family to diversify and occupy various ecological niches, contributing to high species diversity.

Table 1 also shows that species*Stenocatantops splendens* has the highest abundance compared to other species. Based on research results, there is no specific information regarding the factors causing the abundance of *Stenocatantops splendens* to be higher than other species in a habitat. However, the abundance and factors influencing the populations of various species in habitats and ecosystems differ. For example, a study of seasonal abundance and factors influencing the Asian Open-billed Crane population in Raiganj Wildlife Sanctuary, India, found that food availability in the surrounding area and protection from predators were the main factors in increasing the crane population [27]. Another study on the causes of power line collisions and electrocution in birds in Nepal found that bird abundance, distance to agricultural areas, and proximity to human settlements were strongly associated with bird deaths caused by power lines [28]. Hence, abundance*Stenocatantops splendens,* or other species in a habitat can be influenced by various factors such as food availability, protection from predators, and human activities. Further research is needed to determine the specific factors that cause the abundance of *Stenocatantops splendens* to be higher than other species in a habitat.

Differences in the composition and abundance of each species that make up the grasshopper community in Kerandangan TWA affect diversity, including overall species richness, variety, and evenness. The results of descriptive analysis show that the three community variables are relatively low (Figure 3). This is because the value is lower than the diversity in vegetable fields in Suranadi, West Lombok [11]. The number of species is also lower than that found in the rice field ecosystem, Beriri Jarak, East Lombok [12]. In the Dompu savanna, the number of species found was even higher, namely 30 species, with an H' value reaching 2.47 [13]. It also has a higher value than that found in TWA Kerandangan.

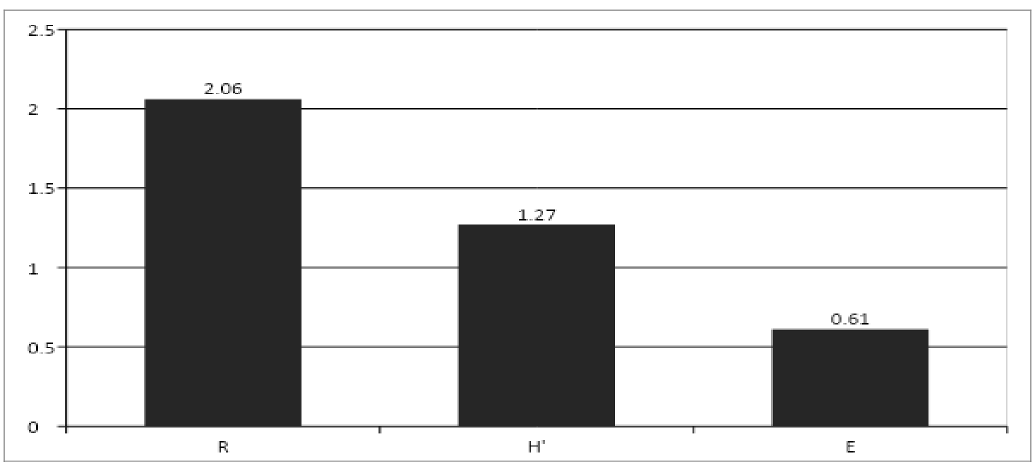

Figure 3. Species richness, diversity index, and evenness of grasshopper species

Grasshopper diversity can be influenced by various internal factors such as genetic drift, gene flow, and migration. Additionally, habitat fragmentation can increase diversity in populations. The ability of populations to adapt to new environmental conditions can also be linked to genetic variation [29]. Habitat factors can have a significant impact on grasshopper diversity. For example, one study found that grasshopper diversity in urban wastelands was primarily driven by habitat factors such as plant cover, human impacts, and accessibility [30]. Another study found that habitat quality indices measured using the InVEST model can explain variations in bird diversity in an urban area [31]. In addition, an analysis of the genetic structure of the grasshopper species Chorthippus parallelus found that land use intensity and habitat structure can impact the organism's genetic structure [32].

Physical factors can influence grasshopper diversity in various ways. For example, temperature, soil moisture, and composition can affect the abundance and diversity of grasshopper species [11]. In addition, topographic factors such as aspect, height, slope, position, curvature of the plane, and curvature of the profile can influence the distribution of grasshoppers [33]. Vegetation cover, plant cover, and accessibility can also impact grasshopper diversity [32]. However, it should be remembered that physical factors do not stand alone and can interact with other factors, such as habitat fragmentation and genetic variation, to influence grasshopper diversity.

Chemical factors can also influence grasshopper diversity. For example, plant secondary metabolites (PSM) produced in response to abiotic stresses can impact grasshopper diversity [34]. PSMs are small molecules with diverse chemical structures and biological activities necessary for human health and are the building blocks of many pharmaceutical drugs. Plants subjected to abiotic stress present a potential alternative source for drug discovery. Plants can conduct defense responses by producing various PSMs to overcome abiotic environmental stressors and avoid cell and tissue damage. Plants synthesize new chemicals or increase the concentration (in most cases) of existing chemicals, including the significant bioactive lead compounds morphine, camptothecin, catharanthine, epicatechin-3-gallate (EGCG), quercetin, resveratrol, and kaempferol. Most PSM produced under various abiotic stress conditions are plant defense chemicals and are functionally anti-inflammatory and antioxidant. The leading PSM group is terpenoids, followed by alkaloids and phenolic compounds.

Human factors can also impact grasshopper diversity. For example, human activities such as deforestation and urbanization can cause habitat loss and fragmentation, which negatively impacts grasshopper diversity [32]. Additionally, human activities can introduce non-native species, which can compete with native grasshopper species and reduce their diversity [35]. Apart from that, human activities can also influence the genetic structure of grasshopper populations. For example, a study of the genetic structure of the bamboo grasshopper Ceracris kiangsu found that human activities such as past climate change, geographic isolation, and ecological factors may influence the evolution of its genetic structure [36]. Various factors can cause human impact on grasshopper diversity in non-urban areas. Here are some examples: Deforestation: Deforestation can lead to habitat loss and fragmentation, which can negatively affect grasshopper diversity [37]. Introduction of non-native species: Human activities can introduce non-native species, which can compete with native grasshopper species and reduce their diversity [38]. Overgrazing: Overgrazing can lead to changes in vegetation cover, which can impact grasshopper diversity [39]. Unsustainable agriculture: Unsustainable agriculture practices can lead to soil degradation and changes in vegetation cover, which can negatively affect grasshopper diversity. Climate change: Climate change can affect grasshopper diversity by altering temperature and precipitation patterns, impacting their distribution and abundance. It is important to note that these factors can interact with each other and other factors, such as physical and chemical factors, to affect grasshopper diversity.

Conclusions

Our findings show 8 species of grasshoppers from 4 different families in Kerandangan TWA. The eight species are *Atractomorpha crenulata*, *Stenocatantops splendens*, *Phlaeoba antennata*, *Oxya hyla intricata*, *Dissosteira carolina*, *Chorthippus Brunneus*, *Valanga Nigricornis*, and *Phaneropterinae sp*. the most abundant species are *Stenocatantops splendens*. Grasshopper diversity is relatively low. This is observed from the values of the species richness, diversity, and evenness indices. Nevertheless, grasshopper conservation remains important in Kerandangan TWA. This is because of its significant role in maintaining ecological processes in the conservation area.

References

[1] Maryati. (2022). *Kerandangan Nature Tourism Park*. Voice of Indonesia: from Indonesia to the World. https://voinews.id/index.php/component/k2/item/18453-kerandangan-nature-tourism-park

[2] Indonesia Window. (2023). *Lombok Island has a variety of attractions*. https://indonesiawindow.com/en/lombok-island-has-a-variety-of-attractions/

[3] AllTrails. (2023). *Kerandangan Nature Park*. https://www.alltrails.com/trail/indonesia/west-nusa-tenggara--2/taman-wisata-alam-kerandangan

[4] Lonely Planet. (2023). *Taman Wisata Alam Kerandangan*. https://www.lonelyplanet.com/indonesia/nusa-tenggara/senggigi/attractions/taman-wisata-alam-kerandangan/a/poi-sig/1584990/356599

[5] Deraison, H., Badenhausser, I., Börger, L., & Gross, N. (2015). Herbivore effect traits and their impact on plant community biomass: An experimental test using grasshoppers. *Functional Ecology*, *29*(5), 650–661.

[6] Pearse, I. S., Duchardt, C., Legg, L., & Porensky, L. M. (2022). Grasshopper Species Composition Differs Between Prairie Dog Colonies and Undisturbed Sites in a Sagebrush Grassland. In *Journal of the Kansas Entomological Society* (Vol. 94, Issue 3, pp. 183–198).

[7] Du, B., Wei, J., Lin, K., Lu, L., Ding, X., Ye, H., Huang, W., & Wang, N. (2022). Spatial and temporal variability of grassland grasshopper habitat suitability and its main influencing factors. *Remote Sensing*, *14*(16), 1–17.

[8] Cumberland, C., Jonas, J. L., & Paschke, M. W. (2017). Impact of grasshoppers and an invasive grass on establishment and initial growth of restoration plant species. *Restoration Ecology*, *25*(3), 385–395.

[9] Heinze, J., Krumpholz, L., Blaum, N., Hoefgen, R., & Ogden, M. (2022). Shoot herbivory by grasshoppers has stronger effects on root morphology than clipping. *Plant Ecology*, *223*(9), 1069–1078.

[10] Cook, R. J., Barron, J. C., Papendick, R. I., & Williams, G. J. (1981). Impact on agriculture of the

Mount St. Helens eruptions. *Science*, *211*(11), 16–22.

[11] Ilhamdi, M. L., Idrus, A. Al, Santoso, D., & Raksun, A. (2022). Diversity of grasshopper in Lingsar Vegetable Field, West Lombok. *Jurnal Pijar Mipa*, *17*(5), 701–705.

[12] Ilhamdi, M. L., Syazali, M., & Almiah, M. (2023). Study of species richness of grasshopper (ordo orthoptera) in Beriri Jarak, Lombok Island, Indonesia. *Jurnal Pijar Mipa*, *18*(2), 279-283.

[13] Leksono, A. S., Yanuwiadi, B., Khotimah, A., & Zairina, A. (2022). Grasshopper diversity in several agricultural areas and savannas in Dompu, Sumbawa Island, Indonesia. *Biodiversitas Journal of Biological Diversity*, *23*(1), 75-80.

[14] Rosinta, M., Artayasa, I. P., & Ilhamdi, M. L. (2021). Diversity of Soil Insect in Kerandangan Ecotourism Nature Park Area West Lombok Island. *Jurnal Biologi Tropis*, *21*(3), 870-877.

[15] Tan, MK (2012). *Orthoptera In The Bukit Timah and Central Catchment Nature Reserves (Part 1): Suborder Caelifera (HTT Wah (ed.)*; Issue Part 1). Raffles Museum of the Biodiversity Research

[16] Tan, MK (2017). *Orthoptera in the Bukit Tin and central catchment nature reserves (part 2): suborder ensifera 2 (HTW Tan (ed.); 2nd Editio, Issue Part 2)*. Lee Kong Chian Natural History Museum.

[17] Iorio, C., Scherini, R., Fontana, P., & Buzzetti, FM (2019). Grasshoppers & Crickets of Italy . WBA Handbooks 10 (October Issue).

[18] Edegbene, A. O., Jazuli, A., Ayuba, I. M., Edegbene Ovie, T. T., & Akumabor, E. C. (2023). Assessing the ecological health of River Ringim, Northwestern, Nigeria using macroinvertebrate-based Chanchaga Multimetric Index. *Water Science*, *37*(1), 71-79.

[19] Oumarou Ngoute, C., Kekeunou, S., & Bilong Bilong, C. F. (2023). Grasshopper (Orthoptera: Acridomorpha) diversity in response to fallow-land use in southern Cameroon with recommendations for land management. *Journal of Insect Science*, *23*(2), 5.

[20] Nursin, L. S. (2021, February). The Diversity Of Grasshoppers (Subordo Caelifera) In The National Park Of Mount Merbabu And Mount Pangonan Central Java. In *Proceeding International Conference on Science and Engineering* (Vol. 4, pp. 133-137).

[21] Syahlan, S. (2016). *Jenis-Jenis Belalang (Orthoptera: Ensifera di dusun III desa Rambah Hilir Tengah Kecamatan Rambah Hilir Kabupaten Rokan Hulu* (Doctoral dissertation, Universitas Pasir Pengaraian).

[22] Ilhamdi, M. L., & Syazali, M. (2021). Diversity of Soil Arthropods in Suranadi Nature Park, Lombok, and its role on science lesson in elementary and secondary school. *Jurnal Biologi Tropis*, *21*(3), 926-937.

[23] Prakoso, B. (2017). Biodiversitas Belalang (Acrididae: ordo Orthoptera) pada Agroekosistem (zea mays l.) dan Ekosistem Hutan Tanaman di KebunRaya Baturaden, Banyumas. Biosfera. 34 (2): 80-88. DOI:

[24] Canedoli, C., Orioli, V., Padoa-Schioppa, E., Bani, L., & Dondina, O. (2017). Temporal variation of ecological factors affecting bird species richness in urban and peri-urban forests in a changing environment: A case study from Milan (Northern Italy). *Forests*, *8*(12), 1–13.

[25] Cabral-De-Mello, D. C., Martins, C., Souza, M. J., & Moura, R. C. (2011). Cytogenetic mapping of 5S and 18S rRNAs and H3 histone genes in 4 ancient proscopiidae grasshopper species: Contribution to understanding the evolutionary dynamics of multigene families. *Cytogenetic and Genome Research*, *132*(1–2), 89–93.

[26] Wang, P., Moore, B. M., Panchy, N. L., Meng, F., Lehti-Shiu, M. D., & Shiu, S. H. (2018). Factors influencing gene family size variation among related species in a plant family, solanaceae. *Genome Biology and Evolution*, *10*(10), 2596–2613.

[27] Pramanik, A. K., Santra, K. B., & Kumar Manna, C. (2014). Seasonal abundance and factors influencing the population of Asian Open-Billed Stork (Anastomus oscitans) in the Raiganj Wildlife Sanctuary, West Bengal, India. *Asian Journal of Conservation Biology*, *3*(1), 28–37.

[28] Hamal, S., Sharma, H. P., Gautam, R., & Katuwal, H. B. (2023). Drivers of power line collisions and electrocutions of birds in Nepal. *Ecology and Evolution*, *13*(5), 1–8.

[29] Sathyan, R., Engelbrecht, A., & Couldridge, V. C. K. (2023). Phylogeographic investigation of the bladder grasshopper Bullacris unicolor (Orthoptera Pneumoroidea) in South Africa. *Ethology Ecology and Evolution*, *35*(5), 650–668.

[30] Eckert, S., Möller, M., & Buchholz, S. (2017). Grasshopper diversity of urban wastelands is primarily boosted by habitat factors. *Insect Conservation and Diversity*, *10*(3), 248–257.

[31] Li, D., Sun, W., Xia, F., Yang, Y., & Xie, Y. (2021). Can habitat quality index measured using the invest model explain variations in bird diversity in an urban area? *Sustainability (Switzerland)*, *13*(10), 1–27.

[32] Wiesner, K. R., Habel, J. C., Gossner, M. M., Loxdale, H. D., Köhler, G., Schneider, A. R. R., Tiedemann, R., & Weisser, W. W. (2014). Effects of habitat structure and land-use intensity on the genetic structure of the grasshopper species Chorthippus parallelus. *Royal Society Open Science*, *1*(2), 1–10.

[33] Li, L. L., Zhao, C. Z., Yin, C. Q., Wang, D. W., & Zhang, J. X. (2012). Grasshopper (Orthoptera: Acrididae) density on natural grasslands in upper reaches of Heihe River, Northwest China in relation with topography: An analysis with generalized additive models (GAM). *Chinese Journal of Ecology*, *31*(12), 3121–3126.

[34] Yeshi, K., Crayn, D., Ritmejeryte, E., & Wangchuk, P. (2022). Plant secondary metabolites produced in response to abiotic product development. *Molecules*, *27*, 1–27.

[35] Sivyer, L., Morgan-Richards, M., Koot, E., & Trewick, S. A. (2018). Anthropogenic cause of range shifts and gene flow between two grasshopper species revealed by environmental modelling, geometric morphometrics and population genetics. *Insect*

Conservation and Diversity, *11*(5), 415–434.
[36] Song, Z., Ze, S., Liu, C., & Chen, B. (2023). New insights into the genetic structure of the outbreak-prone bamboo grasshoppers. *Frontiers in Ecology and Evolution, 11*, 1–13.
[37] Santiago-Alarcon, D., & MacGregor-Fors, I. (2020). Cities and pandemics: Urban areas are ground zero for the transmission of emerging human infectious diseases. *Journal of Urban Ecology*, *6*(1), 1–3.
[38] Tomlinson, S., Lomolino, M., Haythorne, S., Anderson, A., Austin, J. J., Brown, S., Perry, G., Wilmshurst, J., Wood, J. R., & Fordham, D. A. (2023). Reconstructing colonization dynamics to establish how human activities transformed island biodiversity. *BioRxiv*, 1–24.
[39] Ibrahim, E. S., Ahmed, B., Arodudu, O. T., Abubakar, J. B., Dang, B. A., Mahmoud, M. I., Shaba, H. A., & Shamaki, S. B. (2022). Desertification in the sahel region: a product of climate change or human activities? A case of desert encroachment monitoring in north-eastern nigeria using remote sensing techniques. *Geographies*, *2*(2), 204–226.