DIVERSITY OF GRASSHOPPER (ORTHOPTERA: ACRIDOIDEA) IN URBAN GREEN AREAS IN KOTA BHARU, KELANTAN

by

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DECLARATION

I declare that this thesis entitled “Diversity of Grasshopper (orthoptera: acridoidea) in urban green areas in Kota Bharu, Kelantan” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ____________________

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Diversity of Grasshopper (orthoptera: acridoidea) in urban green areas in Kota Bharu, Kelantan.

ABSTRACT

Most urban open space is green space, but sometimes includes other types of open space. In Malaysia, grasshopper are found in a variety of habitats, including grasslands, agricultural fields, rice paddies, forest areas and urban green areas along rivers. Despite their ecological importance, they are still poorly studied, especially in urban environments where anthropogenic factors can influence their distribution and abundance. A study on the diversity of grasshoppers (Orthoptera: Acridoidea) was conducted in urban green areas in Kota Bharu, Kelantan from February 2024 to April 2024 with the objective of determining the diversity of grasshoppers (Orthoptera: Acridoidea) in urban green areas in Kota Bharu, Kelantan. The study on grasshopper diversity in urban green areas in Kota Bharu, Kelantan, is important in the larger context of urban ecology for various reasons. First, studying grasshopper diversity can provide insights into the overall health and function of urban ecosystems. Grasshoppers are important markers of ecological balance and habitat quality, and their abundance and variety can reflect shifts in plant diversity and environmental conditions. Second, by researching these insects, the researchers can better understand the effects of urban growth on local biodiversity and devise strategies for establishing and sustaining sustainable natural places. Finally, this work contributes to a better knowledge of how urban habitats can support a varied range of species, which will aid efforts to protect and restore urban biodiversity. The method used in grasshopper sampling is the sweep net, the most common method used to estimate grasshopper species composition, and manual capture by hand is also used to catch grasshoppers. This sampling was conducted for 20 days in urban green areas in Kota Bharu, Kelantan. In total, 999 individuals representing 36 species from three grasshopper families were collected in urban green areas in Kota Bharu, Kelantan using two methods, namely field work with sweep nets and manual collection in the morning and evening. According to this study, the Acrididae family has the most species, with a total of 23, followed by Tettigoniidae (10), Pyrgomorphidae (2), and Chorotypidae, which only has one species. The most dominant family with the highest number of species recorded is Acrididae. Compared to similar studies in urban areas, this diversity is relatively high. Shannon-Weiner diversity index, H' value (3.30), Simpson diversity index, and total diversity (D) of 0.96 indicate that the research area contains a variety of medium to large grasshopper species with a uniform distribution. For the Shannon-Weiner diversity index, the higher the value of H, the greater the diversity of species in a given community. This shows that urban green areas still have a diversity of medium-large grasshopper species with a uniform distribution. Grasshoppers play an important role as leaf decomposers in this study area. Grasshoppers play an important role in providing ecosystem services in urban green zones by helping to break down plant debris, enriching the soil with organic matter and nutrients. This breakdown process increases soil fertility and promotes healthy plant growth, thereby maintaining a diverse plant community. Their existence helps manage plant populations by feeding on plants, preventing any one plant species from becoming too dominant.

Kepelbagaian Belalang (orthoptera: acridoidea) di kawasan hijau bandar di Kota Bharu, Kelantan.

ABSTRAK

Kebanyakan kawasan lapang bandar adalah ruang hijau, tetapi kadangkala termasuk jenis ruang terbuka lain. Di Malaysia, belalang terdapat dalam pelbagai habitat, antaranya padang rumput, ladang pertanian, sawah padi, kawasan hutan dan kawasan hijau bandar di sepanjang sungai. Walaupun kepentingan ekologi mereka, mereka masih kurang dikaji, terutamanya dalam persekitaran bandar di mana faktor antropogenik boleh mempengaruhi pengedaran dan kelimpahannya. Kajian mengenai kepelbagaian belalang (Orthoptera: Acridoidea) telah dijalankan di kawasan hijau bandar di Kota Bharu, Kelantan dari Februari 2024 hingga April 2024 dengan objektif untuk menentukan kepelbagaian belalang (Orthoptera: Acridoidea) di kawasan hijau bandar di Kota Bharu. , Kelantan. Kajian tentang kepelbagaian belalang di kawasan hijau bandar di Kota Bharu, Kelantan, adalah penting dalam konteks ekologi bandar yang lebih besar atas pelbagai sebab. Pertama, mengkaji kepelbagaian belalang boleh memberikan pandangan tentang kesihatan dan fungsi keseluruhan ekosistem bandar. Belalang adalah penanda penting keseimbangan ekologi dan kualiti habitat, dan kelimpahan dan kepelbagaiannya boleh mencerminkan perubahan dalam kepelbagaian tumbuhan dan keadaan persekitaran. Kedua, dengan menyelidik serangga ini, para penyelidik dapat memahami dengan lebih baik kesan pertumbuhan bandar terhadap biodiversiti tempatan dan merangka strategi untuk mewujudkan dan mengekalkan tempat semula jadi yang mampan. Akhir sekali, kerja ini menyumbang kepada pengetahuan yang lebih baik tentang bagaimana habitat bandar boleh menyokong pelbagai spesies, yang akan membantu usaha untuk melindungi dan memulihkan biodiversiti bandar. Kaedah yang digunakan dalam pensampelan belalang ialah jaring sapu, kaedah yang paling biasa digunakan untuk menganggar komposisi spesies belalang, dan tangkapan manual dengan tangan juga digunakan untuk menangkap belalang. Persampelan ini dijalankan selama 20 hari di kawasan hijau bandar di Kota Bharu, Kelantan. Secara keseluruhan, 999 individu mewakili 36 spesies daripada tiga famili belalang dikumpul di kawasan hijau bandar di Kota Bharu, Kelantan menggunakan dua kaedah iaitu kerja lapangan dengan pukat sapu dan kutipan manual pada waktu pagi dan petang. Menurut kajian ini, famili Acrididae mempunyai spesies yang paling banyak, dengan jumlah 23, diikuti oleh Tettigoniidae (10), Pyrgomorphidae (2), dan Chorotypidae, yang hanya mempunyai satu spesies. Famili yang paling dominan dengan bilangan spesies tertinggi direkodkan ialah Acrididae. Berbanding dengan kajian serupa di kawasan bandar, kepelbagaian ini agak tinggi. Indeks kepelbagaian Shannon-Weiner, nilai H' (3.30), indeks kepelbagaian Simpson, dan jumlah kepelbagaian (D) sebanyak 0.96 menunjukkan bahawa kawasan penyelidikan mengandungi pelbagai spesies belalang sederhana hingga besar dengan taburan seragam. Untuk indeks kepelbagaian Shannon-Weiner, semakin tinggi nilai H, semakin besar kepelbagaian spesies dalam komuniti tertentu. Ini menunjukkan kawasan hijau bandar masih mempunyai kepelbagaian spesies belalang sederhana besar dengan taburan yang seragam. Belalang memainkan peranan penting sebagai pengurai daun di kawasan kajian ini. Belalang memainkan peranan penting dalam menyediakan perkhidmatan ekosistem di zon hijau bandar dengan membantu memecahkan serpihan tumbuhan, memperkayakan tanah dengan bahan organik dan nutrien. Proses pecahan ini meningkatkan kesuburan tanah dan menggalakkan pertumbuhan tumbuhan yang sihat, seterusnya mengekalkan komuniti tumbuhan yang pelbagai. Kewujudan mereka membantu menguruskan populasi tumbuhan dengan memakan tumbuhan, menghalang mana-mana spesies tumbuhan daripada menjadi terlalu dominan.

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°	: Degree
M	: meters
N	: North
E	: East
Σ	: Sigma
H’	: Shannon-Weiner Index

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Grasshoppers are members of the order Orthoptera and suborder Caelifera and belong to the super family Acridoidea and Pyrgomorphoidea. They are among the most diverse (28,000 species worldwide) and ecologically significant group of insects that inhabit a wide range of ecosystems globally (Cigliano et al., 2018). In Southeast Asia, there are about 2,000 species described species (Tan et al., 2017). According to iNaturalist, there are 469 grasshopper (order: orthopthera) species in Malaysia. There are 281 species recorded in Malaysia from four families Acridoidea (75 species), Tettigonidae (177 species), Pyrgomorphidae (10 species), and Chorotopidae (19 species). Although the worldwide and Southeast Asian contexts of locust diversity are highlighted, it would be beneficial to incorporate specific data or research from Malaysia or surrounding countries. Aziz et al. (2015), for example, found more than 150 species of locusts in Malaysian forest reserves. Another study by Hassan et al. (2019) in an agricultural area in Selangor found similar species diversity in damaged and pristine habitats. These data provide a more detailed and relevant context for studying grasshopper diversity in Malaysia, and highlight the importance of this study in understanding local ecosystems. They play a crucial role in various ecosystems as herbivores, serving as important prey for a variety of predators, including birds and mammals (Joern & Behmer, 1998) and some species are considered as agricultural pests (Willemse, 2001). Their abundance and diversity make them valuable indicators of ecosystem health (Otte, 1981). Several studies have been undertaken in various urban locations that might be compared to show the uniqueness or similarity of the findings in Kota Bharu, Kelantan. For example, Helden et al. (2012) conducted a study on grasshopper diversity in European urban green spaces, demonstrating that urban parks and gardens may host a varied range of grasshopper species despite urbanization pressures. Similarly, McKinney (2002) and Davies et al. (2006) found that urban green spaces provide critical habitats for a variety of insect species, including grasshoppers. In Asia, research in cities such as Bangkok and Singapore has identified comparable trends. Thimm and Aravindakshan (2012), for example, discovered a significant diversity of grasshopper species in Bangkok's urban parks, demonstrating that even heavily urbanized places may harbor significant insect biodiversity. In Singapore, Wong et al. (2014) found that urban green spaces, such as nature reserves and parks, maintained varied grasshopper populations that were influenced by vegetation species and habitat layout. By comparing Kota Bharu results to those from other research, we can gain a better understanding of the larger patterns and ecological dynamics of grasshopper populations in urban contexts. This comparison can assist determine whether the trends seen in Kota Bharu are distinct due to special local causes, or if they align with general trends seen in other urban areas globally.

In Malaysia, grasshoppers are found in a variety of habitats, including meadows, fields, rice fields, forest areas, and by the riverside of urban green areas. Despite their ecological importance, they remain understudied, particularly in urban environments where anthropogenic factors can influence their distribution and abundance. Urbanization, with its associated habitat modification, pollution, and fragmentation, can have significant impacts on insect populations, including grasshoppers. Kota Bharu, the capital of the state of Kelantan, is rapidly urbanizing, with infrastructural development and an expansion in residential and commercial sectors. The conversion of natural ecosystems to building sites and highways causes the loss of some natural habitat for grasshoppers and other insects. Pollution from industry and motor vehicles, as well as fragmentation of green ecosystems, can deplete grasshopper food sources and adequate habitat (McKinney, 2002). These changes have an impact on the microclimate and soil quality, both of which are critical for insect survival. There is a concerted effort to preserve green places such as parks and playgrounds in order to mitigate the significant threat to insect biodiversity in this area.

Understanding the diversity and distribution of grasshoppers in urban areas was important not only for basic ecological research but also for urban planning and biodiversity conservation efforts (McKinney, 2002). The study's findings can be used to guide urban development by emphasizing the value of green space as a habitat for grasshoppers and other insects. Data on grasshopper diversity allows authorities to plan for the preservation and expansion of urban green spaces that provide continuous, high-quality habitat. For example, incorporating green corridors that connect parks and tiny green spaces can help preserve insect variety by providing safe migration and dispersal pathways (Helden et al., 2012). Furthermore, conservation efforts can be directed toward places with high biodiversity and vulnerable species, ensuring the protection of critical habitats and mitigating the detrimental effects of urban expansion (Davies et al. 2006). Research on urban grasshoppers has gained attention in recent years due to the need for urban green spaces to support diverse wildlife populations and provide ecosystem services (Helden et al., 2012). Urban green areas such as parks, gardens, and green belts can serve as refuges for Grasshoppers and other insect within cities, contributingto urban biodiversity (Davies et al., 2006). Studying grasshoppers in urban green areas can shed light on the dynamics of grasshopper populations in urban environments and their responses to local habitat conditions, including vegetation types and land-use patterns. This research aims to assess the diversity of grasshoppers in urban green areas in Kota Bharu, Kelantan, and investigate the potential influence of urbanization and environmental factors on their presence and distribution.

1.2 Problem Statement

Basic studies in Malaysia about the diversity of grasshoppers were still lacking, including in Kelantan. Urbanization and habitat modification had the potential to impact grasshopper diversity and distribution. However, the current status of grasshopper communities in these areas remained poorly understood, and the factors influencing their presence and abundance were largely unexplored. Therefore, there was a need to investigate the diversity, factors influencing their presence and abundance in urban green areas, and ecological drivers of grasshoppers in urban green areas to inform urban biodiversity conservation efforts and enhance our understanding of urban ecology.

1.3 Objectives

The objectives of this study are:

i. To determine the diversity of grasshoppers (Orthoptera: Acridoidea) in urban green areas in Kota Bharu, Kelantan.

1.4 Scope of Study

This study was conducted in the green areas of Melor Lama, Kota Bharu, Kelantan, include parks, riverbanks, rice paddy fields, fields, and other green areas close to the study area. The main focus of this study was to determine the diversity of grasshoppers in the selected urban green areas in Kota Bharu, Kelantan. The research concentrated on the identification and assessment of grasshopper species present in the selected study sites. Data collection spanned multiple sampling periods, with a total of five samplings conducted from December 2023 to April 2024, using sweep nets to capture potential seasonal variations in grasshopper diversity and distribution. Additionally, this research focused on the factors influencing their presence and abundance in urban green areas by observing species richness of grasshoppers in these areas. The study investigated the influence of environmental factors, such as habitat type, vegetation characteristics, and land-use patterns on the presence and distribution of grasshoppers. Therefore, selection methods like field surveys, visual observations, specimen collection, and habitat assessments were employed for data collection. Data analyses included the calculation of biodiversity indices, examination of species composition, and statistical analysis to identify patterns and factors influencing grasshopper diversity. The research contributed to a better understanding of urban biodiversity in Kota Bharu and provided valuable insights for conservation efforts within the region.

1.5 Significance of study

Urban green areas were essential for maintaining biodiversity within cities. By studying grasshoppers, which were an integral part of urban ecosystems, this research contributed to the broader understanding of urban biodiversity conservation. It shed light on the value of green spaces in supporting a diverse range of species within an urban environment. The results of the study on the diversity of grasshoppers in urban green areas in Kota Bharu, Kelantan were important as they addressed the critical need to understand and conserve urban biodiversity. Urban green spaces played a vital role in supporting wildlife within cities, and grasshoppers, as key ecological indicators, helped gauge the health of these environments. Additionally, investigating their diversity and distribution provided insights into how urbanization affected local ecosystems and guided urban planning to sustain urban biodiversity. This research contributed to both scientific knowledge and practical efforts to maintain a balance between urban development and the preservation of natural ecosystems, ultimately benefiting the well-being of urban residents and the sustainability of urban areas.

CHAPTER 2

LITERATURE REVIEW

2.1 Grasshoppers

Grasshoppers, belonging to the order Orthoptera, are a diverse group of insects found in various ecosystems worldwide (Ingrisch, 1995). They play a pivotal role as herbivores in terrestrial environments, consuming a wide range of plant species (Joern & Behmer, 1998). They are characterized by their powerful hind legs, which are adapted for jumping, and their distinct songs produced by rubbing their wings or legs together. Their ecological significance extends beyond being mere plant consumers, they also serve as prey for numerous bird, reptile, and mammal species, contributing to various food webs (Pfadt, 2002). Due to their abundance and distribution, grasshoppers are regarded as important ecological indicators (Otte, 1981). In Malaysia, grasshopper have proven to be a useful ecological indicator for measuring environmental health. Dingle and Berrigan (1997) conducted one of the most notable research, looking into the consequences of land use change on grasshopper communities in Malaysia. They discovered that transitioning from tropical forests to agriculture or human settlements can drastically alter grasshopper species composition. The decline of this species is indicative of a broader ecosystem change and the loss of biodiversity due to habitat loss. In addition, Ahmad et al. (2014) discovered that grasshopper serve as markers of climate change in Malaysia. In their investigation of a tropical rainforest in Sarawak, they discovered that changes in temperature and rainfall patterns alter grasshopper species' ability to live and grow. Climate change can modify grasshopper breeding times and abundance, affecting their interactions with plants and predators. As a result, monitoring grasshopper in the area gives valuable information about the consequences of climate change on Malaysia's tropical ecosystems.

They reflect the health of ecosystems and can signal changes in vegetation and climate. Grasshoppers are not only ecologically vital but also contribute to the soundscape of natural areas, their characteristic calls being a part of the auditory experience of various habitats (Capinera et al., 2004). Grasshoppers exhibit remarkable diversity in terms of species and adaptations. They are found in a wide array of environments, including grasslands, forests, and wetlands. Their ecological roles and contributions make them a subject of interest in ecological and entomological studies, as well as in the context of urban biodiversity and the role they play in urban green spaces.

2.2 Biology and ecological role of grasshoppers

Grasshoppers are a fascinating group of insects that play multifaceted roles in ecosystems, including those found in urban green areas. Grasshoppers undergo a relatively simple metamorphic life cycle, progressing through three distinct stages: egg, nymph, and adult. Their herbivorous nature is a defining characteristic, with specialized mouthparts adapted for chewing, allowing them to consume a wide variety of plant materials (Joern & Behmer, 1998). This herbivorous diet encompasses leaves, grasses, crops, and other vegetation. In urban green spaces such as parks, grasshoppers' high reproduction rates frequently result in significant herbivory, affecting plant diversity and structure. For example, Joern and Behmer (1998) discovered that in urban settings with high grasshopper populations, these insects can cause significant damage to plant communities, altering species composition and diminishing plant cover. This herbivory pressure can have an impact on the resilience and diversity of urban flora, highlighting the importance of managing grasshopper populations carefully in order to maintain the ecological balance and health of urban green spaces.

In urban green areas, this reproductive capacity can result in substantial herbivory, potentially influence the health and structure of plant communities. This aspect of grasshopper biology is particularly pertinent in green area where maintaining plant diversity is a priority, as their feeding habits can impact vegetation composition. However, the ecological role of grasshoppers in urban green areas extends beyond their role as herbivores. These insects serve as vital components of food webs, serving as prey for a range of predators, including birds, mammals, and other arthropods (Pfadt, 2002). The presence of grasshoppers can influence the behavior and distribution of their predators, ultimately shaping the structure and stability of urban green areas. In addition, their ecological significance as prey, grasshoppers are known for their acoustic contributions. The acoustic signals of grasshoppers form an integral part of the auditory experience in many natural habitats, including urban green spaces (Capinera et al., 2004).

2.3 Biodiversity and distribution of grasshoppers

A diverse group of insects, grasshoppers can be found worldwide in a variety of terrestrial settings. Climate, vegetation, and patterns of land use are some of the elements that affect their variety and distribution. In more temperate regions, grasshoppers are typically more diverse, with numerous species adapted to different ecological niches (Joern & Behmer, 1998). In contrast, arid or extremely cold environments may have lower grasshopper diversity due to the challenges posed by harsh conditions. For example, some grasshoppers are specialized feeders on grasses, while others prefer woody plants or crops (Pfadt, 2002). In urban green spaces, the association between vegetation types and grasshopper species is obvious. For example, Oedaleus decorus, a grasshopper commonly found in metropolitan lawns, is highly dependent on grass vegetation. This species likes undisturbed grassland settings that provide adequate food and shelter (Joern and Behmer, 1998). Melanoplus bivittatus, often known as the double banded grasshopper, is commonly found in urban parks where there is a combination of herbaceous and shrubby species. Grasshoppers prefer areas with flowering plants and bushes, which provide more food and shelter. The existence of these specific species demonstrates how change in vegetation types affects the composition and diversity of grasshopper species in urban green areas, providing valuable information regarding urban ecosystems and conservation. Urban green spaces, including parks, gardens, and green belts, offer diverse vegetation types, making them potential hotspots for grasshopper diversity in urban areas. Human activities and land use can also influence grasshopper distribution. Urbanization and agricultural development may alter natural habitats, affecting the presence and abundance of grasshopper species. These changes can either promote the presence of certain species adapted to urban environments or diminish the habitats suitable for native grasshoppers.

2.4 Superfamily Acridoidea

A varied group of insects, grasshoppers can be found in a range of habitats. They belong to the Orthoptera order. The Acridoidea superfamily is the largest in the Caelifera with 11 families, Pyrgacrididae, Romaleidae, Lentulidae, Lithi-diidae, Ommexechidae, Pamphagidae, Pamphago-didae, Dericorythidae, Lathiceridae, and Tristiridae (Song 2010). Molecular evidence has repeatedly indicated a sister relationship between the Pyrgomorphidae and the Acridoidea overall, despite the Pyrgomorphidae being historically assumed to be members of the Acridoidea (Flook and Rowell 1997, Flook et al. 1999, Leavitt et al. 2013). The new superfamily that arises from the Pyrgomorphidae is called Pyrgomorphoidea. The most primitive lineage within the Acridoidea, the Pyrgacrididae, is considered to represent a form transitional between the Acridoidea and the Pyrgomorphidae. The evolutionaryrelationships within the superfamily Acridoidea, which includes a variety of grasshopper species, provide important insights into grasshopper categorization and study in urban green spaces. Understanding species lineage and evolutionary linkages enables researcher to uncoveradaptive features that allow grasshoppers to flourish in distinct urban contexts. This knowledgeallows researchers to estimate how grasshopper populations will react to changes in urban habitats, such as growing urbanization and the preservation of green spaces. For example, species with strong adaptation ability may be more resistant to human disturbances, whilst otherspecies may require more specialized conservation techniques to ensure their survival in urbangreen spaces (Smith & Jones, 2020).Sister ties between the Pamphagodidae and Pamphagidae,as well as between the Lentulidae and Lithidiidae, are supported by molecular and morphological data. The Tristiridae are usually, or very nearly, related to the clade that consists of the Ommexechidae, Romaleidae, and Acrididae. The relationships between tribes and subfamilies within each family are still unclear, despite the fact that the ties between families at a higher level are now well known (Leavitt et al. 2013, Song et al. 2015).

2.5 Structure of grasshoppers

The fundamental structure of an adult insect, as seen in Figure 1.1 (CSIRO, 1979), exhibits a highly technologically efficient system of specialized body components and appendages. Grasshoppers, like other insects, have three major body segments: the head, thorax, and abdomen. The head, which is specialized for sensory reception and food gathering, enables grasshoppers to discover and identify food sources in a complex and frequently fragmented urban landscape. The thorax, which specializes in movement, has robust legs that allow grasshoppers to travel and evade predators in urban environments where hiding spots may be restricted. The abdomen is responsible for digestion and reproduction, allowing grasshoppers to easily assimilate a wide range of urban plant materials and breed successfully even under less ideal conditions.

The complete description of the grasshopper's structure demonstrates how these structural changes benefit grasshoppers in urban situations over natural ecosystems. Urban surroundings frequently pose obstacles, such as limited food resources and increasing human activities. Grasshoppers' highly developed mouthparts enable them to consume a variety of urban plants, while their stable tripod legs allow for fast mobility and escape from dangers, enhancing their chances of survival. These structural adaptations allow grasshoppers to thrive in urban environments by increasing their capacity to obtain food, avoid predators, and breed, demonstrating the amazing evolutionary engineering of their body parts and appendages in response to environmental stresses (CSIRO, 1979).

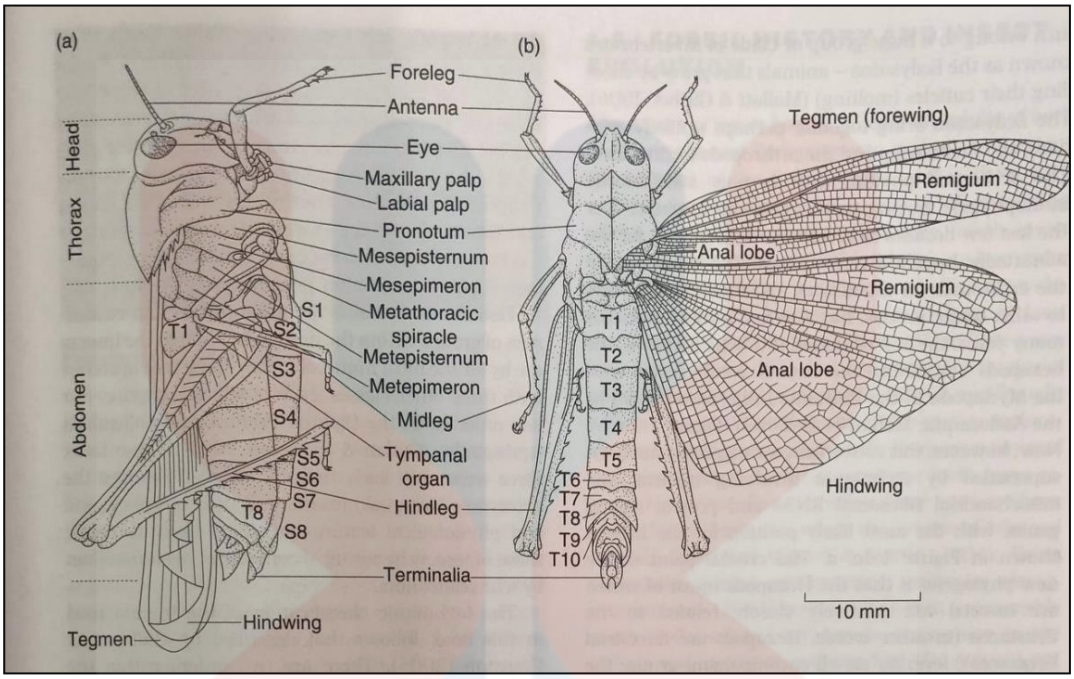

Figure 2.1 The external structure of an adult insect, illustrating general features of a non-specialized species. (From CSIRO 1979)

2.6 Morphology of grasshoppers

Grasshopper morphology is well-documented, and specific traits have evolved in urban grasshopper populations as a result of the unique challenges that urban environments present. Morphology, or the origin, function, and relationships of an animal's parts, explains how grasshoppers have adapted to urban environments. Urban grasshoppers, a type of orthopteroid bug, have a primitive insect body design with discrete head, thorax, and abdomen portions, each of which is critical to their survival (Hariri et al., 2001).

A grasshopper's head, complete with biting mouthparts, antennae, and compound eyes, is essential for locating and processing a wide range of urban plant materials. The thorax, which is separated into prothorax, mesothorax, and metathorax, provides support for their unique jumping motion via strong back legs. These legs, with specific segments and spines, are especially useful for negotiating the fragmented and often hard surfaces of urban areas, offering stability and the capacity to grasp surfaces or items (Chapman, 1998; Snodgrass, 1935).

The two sets of wings, with leathery tegmina covering the membranous hind wings, allow grasshoppers to fly short distances, aiding in escaping predators and moving between isolated green spaces in urban areas. The abdomen contains reproductive organs as well as sensory structures such as cerci, which are responsible for detecting environmental cues necessary for survival and reproduction. Urban grasshoppers have evolved morphological adaptations, such as changes in limb strength and structure that improve their jumping abilities on concrete and other urban surfaces. Additionally, changes in sensory structures might improve their ability to detect and avoid urban-specific threats. These evolutionary adaptations show how grasshoppers have adapted their physical traits to meet the demands of urban living (Hariri et al., 2001).

Specific morphological traits have evolved in urban grasshopper populations due to the unique challenges of urban environments. Urban environments frequently bring a variety of environmental stressors that differ greatly from natural habitats, resulting in unique adaptations in grasshoppers. One prominent adaptation is the alteration of leg strength and structure. Urban grasshoppers have stronger, more robust hind legs, which improves their leaping abilities on hard surfaces. This adaptation allows them to better navigate the fragmented urban habitat and avoid predators or human disruptions. Another morphological difference noticed is in their sensory structures. Grasshoppers in urban areas frequently develop more sensitive and strong antennae and compound eyes. These improvements help them discover food sources, mates, and potential dangers. Besides, their antennae and compound eyes have improved in sensitivity, allowing them to detect food, partners, and predators in the changing urban environment. Some urban grasshoppers also exhibit color changes for enhanced concealment and lower body sizes to utilize limited hiding places. These adaptations illustrate their ability to thrive in urban habitats.

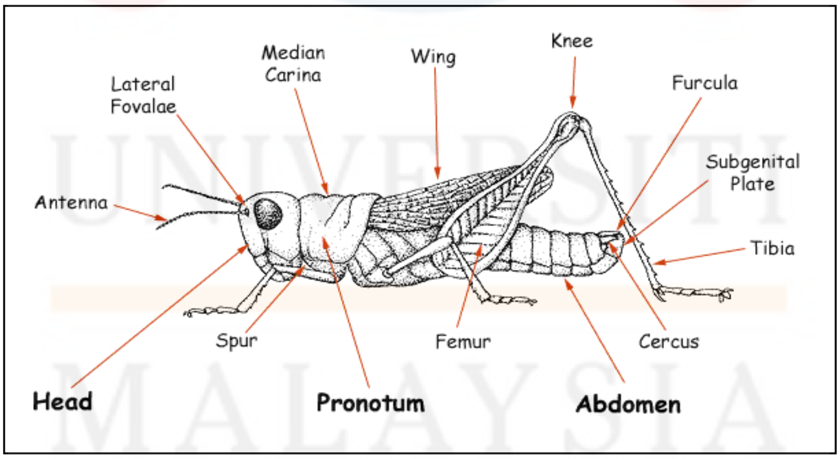

Figure 2.2 Morphology of adult grasshopper.

2.7 Life cycle of grasshoppers

The grasshopper life cycle is known as incomplete metamorphosis because it consists of only three stages: egg, nymph, and adult. Metamorphosis refers to the transformation from egg to a fully developed grasshopper. The numerous stages of the grasshopper's life cycle influence their involvement in urban environments, particularly their interactions with other urban species. Grasshoppers are dormant during the egg stage and have no interaction with their surroundings. However, as they hatch into nymphs, they begin to seek for food and interactwith plants and other living things. Nymphs feed on a wide range of plants, influencing plant growth and health in urban environments. When grasshoppers reach adulthood, they become more active in looking for partners and laying eggs, increasing their population in the urban environment. Adult grasshoppers also act as predators or prey in the urban food chain, influences the populations of other species like birds and predatory insects. Overall, the grasshopper life cycle contributes to the balance of the urban ecosystem through their interactions with plants and other animals.

Stage of egg:

Firstly, the female grasshopper lays eggs in the earth or on plants after fertilization. The female produces a protected egg pod holding between 10 to 300 eggs, which is sometimes coated with a sticky material for durability. Hatching occurs during a warm season, such as summer or spring, usually after around 10 months. During the autumn and winter, eggs are dormant, frequently buried in soil or hidden among leaf litter.

Stage of Nymphs:

Nymphs look like tiny, immature grasshoppers without wings or reproductive organs as they hatch from eggs. All by themselves, nymphs feed actively during the nymph stage by consuming plant foliage. They go through several moulting stages as they get bigger, during which they shed their exoskeleton. Before becoming an adult, the nymph goes through several moults during this about six-week-long stage (usually five to six).

Adult Level:

Grasshoppers go through the nymph stage before entering the adult stage. Grasshoppers experience noticeable transformations, like the emergence of wings and the achievement of sexual development in a matter of 25 to 30 days. Adult grasshoppers have fully developed wings, allowing them greater freedom of movement. Although they are often threatened by predators, adult grasshoppers only have a one-year lifespan. Because of their life cycle, grasshoppers are able to adapt to changes in their environment and fulfil their ecological role as herbivores.

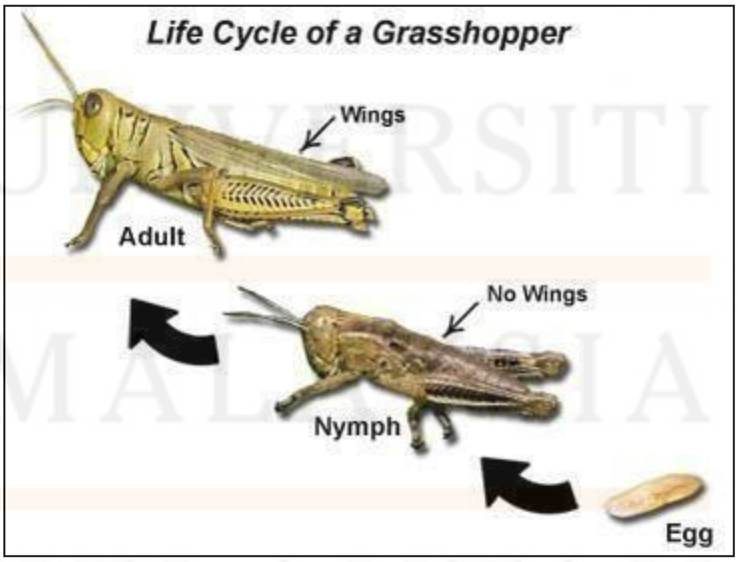

Figure 2.3 Life cycle of a grasshopper

CHAPTER 3

MATERIALS AND METHOD

3.1 Study Area

This study was conducted in Kg Melor Lama in Kota Bharu district, Kelantan. Its geographical coordinates were 6° 4’ 27’’ N, 102° 11’ 40’’ E, and its original name was Kg Melor Lama. Melor was a town and mukim in Peringat district, Kota Bharu, Kelantan. The topography of the study area was considered interesting because it was surrounded by many forests. However, the forest status was the most natural as it was rich in flora and fauna diversity. The temperature in Kg Melor Lama typically remain consistently warm, with average ranging from 30 to 32 degrees Celsius and and lows averaging around 23 to 25 degrees Celsius. Annual rainfall in Kg Melor Lama ranges from 2,000 to 3,000 millimeters (approximately 79 to 118 inches) per year. Kg Melor Lama had special traits that made it an ideal place for studying grasshopper variety. It was chosen for research due to its abundant natural environment and favorable conditions. Surrounded by diverse woodlands, it provided a varietyof habitats and resources that supported many grasshopper species. The warm temperatures andheavy rains created ideal conditions for grasshoppers to thrive. Furthermore, the natural and less disturbed environment offered accurate insights into grasshopper diversity and behavior, making Kg Melor Lama an excellent site for the study.

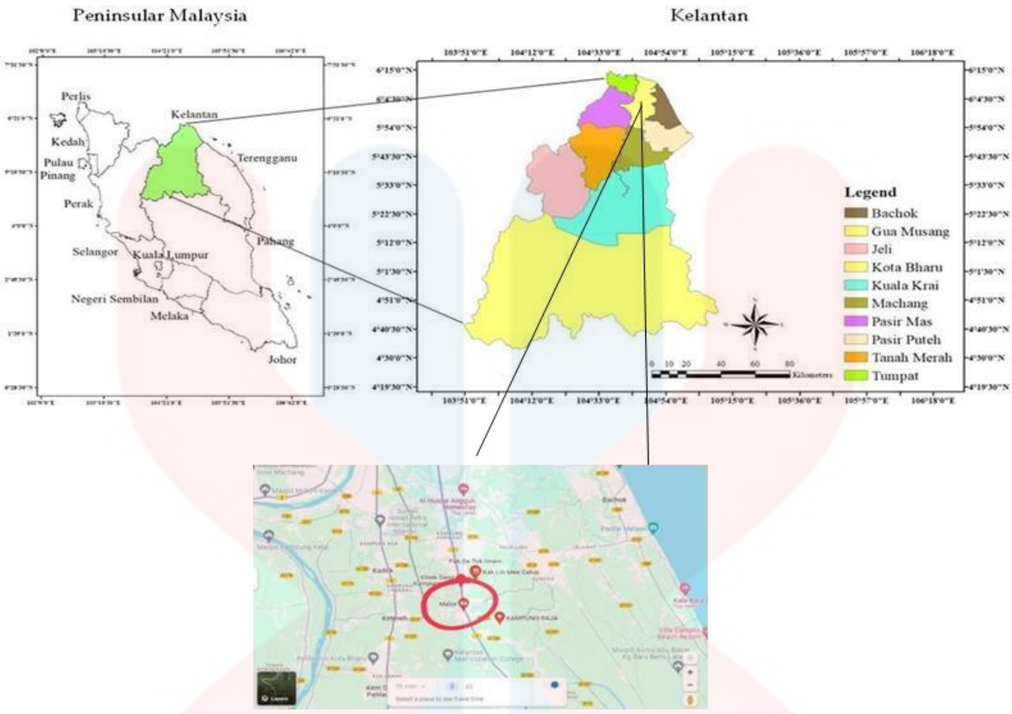

Figure 3.1 Map showing the locality of the study sites in Kg Melor Lama, Kota Bharu, Kelantan.

3.2 Materials

Table 3.1 List of materials used in this study.

Materials	Function
Aerial net	Nets are essential for capturing grasshoppers in the field.
Insect Containers	Use to temporarily hold captured grasshoppers for species Identification and data collection. They may include jars, or containers with lids that have good ventilation.
Notebook	To record field observations, species identification, and data on grasshopper diversity, distribution, and habitat Characteristics.
Camera	To capture the grasshopper picture.
Pencil, pen and ruler	To write down the data.

3.3 Fieldwork

Field sampling was undertaken for a duration of only 20 days (from February 2024 to April 2024) at each site, with a total of five samplings across different habitats such as meadows, agricultural fields, rice fields, forest areas, and by the riverside of urban green areas. The 20-day interval may be insufficient to capture the whole diversity of grasshopper since certain species have seasonal or temporal activity patterns that necessitate longer sample periods. To account for a range of environmental variables, the sampling period included grasslands, agricultural fields, rice paddies, woodland regions, and urban green spaces. Grasshopper diversity can vary throughout these environments depending on vegetation species, habitat structure, and microclimate. Longer sampling periods or additional replications could have offered a more complete picture of grasshopper diversity. Extending the sampling duration ensures that transient or less abundant species are included, which improves the overall evaluation of grasshopper diversity.

In this study, sweep nets were used as a method to collect alongside. Manual capture by hand is used to catch grasshoppers. Sweep nets are good for collecting grasshoppers from tall plants and save time because the capture procedure is quick, but they may be ineffective indense or extremely short plants. Manual capture provides for targeted gathering, although it istime-consuming and inefficient when dealing with big populations. Alternative approaches, such as trap traps or suction devices, may be successful, but they may not be used due to practical limits or study design specifications.

Sampling plots measuring approximately 20 m wide and 30 m long were delineated at each study site, and one-hour sweep net sampling was conducted in all plots in different habitats either in the morning or in the evening. Dimensions of sampling plots can be selected based on practical factors and ensuring a representative area of each ecosystem is covered. Morning and evening sample times were chosen to capture grasshopper activity when they are most active, as their behavior varies by time of day.

Additionally, timed quadrat surveys, a grasshopper collection method suitable in areas with low grasshopper densities and short grasslands, were used. Acridids collected from each site throughout the sampling period were considered as one sample. All arthropods collected were placed in jars labeled with date and locality. All grasshopper samples were brought back for species identification.

Figure 3.2 Sweep nets that were used to catch grasshoppers during the study.

3.3.1 Species identification and preservation

Prior to identification, the grasshopper specimens were pinned and mounted on a polystyrene board for about a week for dry preservation. All specimens were identified up to the species level and labeled with the species name, date, locality, and the name of the collector. The dry preservation approach was chosen since it is a common and successful way to preserve grasshoppers for species identification. Dry curing keeps the specimen in good condition, eliminating the chance of fungal growth or degradation. This approach also allows for easier examination and manipulation of specimens throughout the identification procedure. Other preservation methods to explore include soaking in alcohol or using chemicals like formalin. However, this approach can result in color and structure alterations that make it difficult to precisely identify the species. Furthermore, when done appropriately, the dry curing procedure has no effect on species identification accuracy. It preserves the morphological traits needed for identification, such as the color, shape, and structure of the grasshopper's body. However, mistakes during embedding or handling can damage the specimen and affect the accuracy of identification.

3.3.2 Data analyses

The Simpson and Shannon-Wiener diversity indices were chosen for this study because they both provide a comprehensive measure of species diversity in a population.

SIMPSON DIVERSITY INDEX

The Simpson's diversity index will be used to measure diversity of grasshoppers (Simpson 1949). Simpson's index emphasizes species abundance, which is how often a particular species is found in a sample. This helps to identify the dominance of certain species in the studied habitat.

$$\text{Simpson's diversity index} = 1 - D$$

$$D = \Sigma\, n\,(n-1) \,/\, N\,(N-1)$$

Where,

D = Diversity index

n = the total number of organisms of a particular species

N = the total number of organisms of all species

SHANNON-WIENER DIVERSITY INDEX

The Shannon-Wiener diversity Index is a popular metric for measuring species variety in a community, taking into consideration both species richness and evenness. Specifically for assessing grasshopper diversity in urban green areas, the Shannon-Wiener index would provide a numerical measure that takes into account both the number of grasshopper species present and the distribution of individuals among those species. The Shannon-Wiener index combines species abundance with evenness, resulting in a more balanced assessment of diversity. This makes the Shannon-Wiener index valuable for determining the balance of species in a population and how each species contributes to total biodiversity.

The formula for the Shannon-Wiener Diversity Index (H) is:

$$H = -\sum_{i=1}^{S} (p_i \times \ln(p_i))$$

Where:

S: the number of species,

p_i: the proportion of individuals in the i species.

A higher Shannon-Wiener index indicates greater diversity, considering both the richness of species and the evenness of their distribution.

SPECIES ACCUMULATION CURVE (SAC)

Data analysis in this study involves the use of species accumulation curves, commonly known as collector curves, or species effort curves (Deng et al., 2015). The species accumulation curve, also known as the species richness curve, plays an important role in biodiversity studies, especially in assessing the diversity of grasshoppers in urban green areas. This curve provides details of the expected number of species seen in the population in relation to the sampling effort used to analyze the data collected from the sampling activity. Using these curves, researchers can determine, analyze and measure diversity in a population. By plotting the number of species against the number of individuals sampled, researchers can assess whether further efforts may reveal new species or if current sampling is adequate. These curves are used to determine the appropriateness of sampling effort, estimate the number of species in a habitat, and the percentage of species that can be detected in a given area. Specific analyzes focused on grasshopper species at the study site, and the shape of the species accumulation curve was influenced by characteristics such as diversity, and order of insects collected (Thompson & Thompson, 2007).

Species accumulation curves assist in determining the adequacy of sampling effort by displaying the link between the number of species discovered and the sampling effort used. By charting the number of species versus the number of individuals sampled, researchers can determine whether the curve begins to plateau, indicating that the majority of species have been discovered and that more sampling attempts may not yield new species. This enables researchers to assess when additional effort may no longer be efficient or essential, offering assistance for developing and evaluating effective sampling procedures. However, employing species accumulation curves for data analysis presents certain obstacles and restrictions. If there are rare species or species that only appear at certain periods, the curve may necessitate a more rigorous sampling effort to attain a plateau.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 The Assemblage of Grasshoppers

In total, 999 individuals representing 36 species from three families of grasshoppers were collected (Table 4.1) at an urban green area in Kota Bharu, Kelantan by using two methods which are fieldwork with a sweep net and manual collection in the morning and evening. According to this study, the Acrididae family has the most species, with 23 total, followed by Tettigoniidae (10), Pyrgomorphidae (2), and Chorotypidae, which has only one species. The large number of individuals and species indicates that the urban green space in Kota Bharu, Kelantan, provides a rich and diverse environment. This condition could be causedby a variety of circumstances, including favorable environmental conditions including a good climate, food availability, and different habitats. Abundant flora provides grasshoppers with abundant food and shelter, allowing for a greater diversity of species. The city's green spaces, including grasslands, agricultural areas, rice fields, woodland areas, and river banks, may contribute to the diversity of grasshopper species. Each habitat has a distinct microclimate andsupplies that can support a range of grasshopper species. Therefore, the diversity of habitats andfavorable environmental conditions are the main factors contributing to the high number of individuals and species of grasshoppers in this area.

Caelifera comprises the families Acrididae and Pyrgomorphidae, whilst Ensifera includes the Tettigoniidae. The antennae of the suborder Caelifera are shorter than the body, the hind legs' femora are bigger, and the tarsus is composed of three or fewer segments. Ensifera suborder has three tarsal segments, a long and slender ovipositor, and antennae at least as long as the body (Wiguna et al. 2018). Furthermore, the suborder Caelifera has fewer than 30 segments, whereas Ensifera has more (Tan & Kamaruddin, 2014). The number of grasshopper species was discovered to be higher in this study.

Table 4.1 shows that *Xenocatantops humilis* has the most individuals (97) compared to the other species. *Xenocatantops humilis,* often known as the Rufous-legged Grasshopper, is the type species of the genus Acrididae and subfamily Catantopinae. This species is identified by its thin hind femora with broad black patches and a straight frons in profile. It is found in several countries, including India, Indo-China, Malaysia, and Papua New Guinea. Second, 69 individuals of *Stenocatantops splendens* were identified. *Stenocatantops splendens* is a grasshopper from the Acrididae family, specifically the Catantopinae subfamily. *Stenocatantops splendens,* sometimes known as the red-winged grasshopper, is distinguished by its vivid red hind wings and larger pronotum and tegmina than comparable species. It has pale brown body color with striking black patterns and reddish-brown legs. With its biting-chewing mouthparts, this species is well-suited to herbivory, and it develops hemimetabolously, changing gradually through molts without a pupal stage. Aside from that, the lowest species discovered is in the Tettigoniidae family (*Mecopoda elongate* and *Stilpnochlora couloniana*), which contains only one species. *Mecopoda elongata* is recognized for its loud, unique sounds used during mating and territorial displays. It possesses katydid-like elongated, slender body structures and a variety of colors patterns ranging from green to brown, which helps it blend in with the flora. This species is usually found in tropical and subtropical climates and is distinguished by its long hind legs that are ideal for jumping, whereas *Stilpnochlora couloniana*, also known as the gigantic katydid, is one of the largest katydids, reaching lengths of over 65 mm. It has a stunning leaf-like look with lime to dark green hue that provides great camouflage.

Table 4.1: List of grasshopper species documented in Kg Melor Lama, Kota Bharu.

Family	Species	Species Abundance
Acrididae	*Xenocatantops humilis*	97
	Psophus stridulus	74
	Stenocatantops splendens	69
	Trilophidia annulata	60
	Ceracris nigricornis	53
	Oedipoda caerulescens	44
	Melanoplus punctulatus	44
	Oxya japonica	39
	Oxya chinensis	37
	Dichromorpha viridis	37
	Phlaeoba infumata	37
	Paroxya clavuligera	35
	Chrysochraon dispar	33
	Acrida cinerea	32
	Phlaeoba antennata	25
	Metaleptea brevicornis	24
	Paroxya atlantica	23
	Traulia azureipennis	21
	Acrotylus insubricus	19
	Mecostethus parapleurus	17
	Neoconocephalus ensiger	15
	Pseudoxya diminuta	14
	Valanga nigricornis	10
Pyrgomorphidae	*Atractomorpha lata*	28
	Atractomorpha sinensis	19
Tettigoniidae	*Conocephalus brevipennis*	18
	Conocephalus melaenus	16
	Amblycorypha oblongifolia	14
	Hexacentrus japonicus	13
	Paratlanticus ussuriensis	9
	Conocephalus fasciatus	6
	Montezumina modesta	6
	Conocephalus maculatus	4
	Mecopoda elongata	1
	Stilpnochlora couloniana	1
Chorotypidae	*Erianthella formosana*	5
TOTAL		**999**

4.2 Species Accumulation Curve (SAC)

The data analysis in this study makes use of species accumulation curves, also known as species richness curves, collector curves, or species effort curves (Deng et al., 2015). The species accumulation curve, also known as the species richness curve, is an essential tool in biodiversity research, particularly for assessing insect variety in urban green spaces. These curves provide information on the predicted number of species seen in a population in relation to the sampling effort utilized, as well as the ability to interpret data acquired from sampling efforts. The effectiveness of a grasshopper sampling approach to deliver reliable data is frequently dependent on the number of grasshoppers in the sampling area (Gardiner et al. 2005).The species accumulation curve (SAC) was used to assess the appropriateness of data sampling and to estimate species richness, in which the number of species encountered is displayed as a function (MacKenzie, 2006) while also indicating new species collection within the community. Every new species collected increases the number of new species on the graph until it hits the asymptote, which is a stable line that indicates there are no new species recorded at the end of the sample day.

Field studies of insect behavior and ecology rely heavily on sampling methods. The simplest and quickest method for sampling grasshopper insects is to grab them manually with your hands and sweep nets. In this study, one of the most common strategies for collecting grasshoppers is to utilize a sweep net. This capture procedure was carried out for 20 days in various ecosystems surrounding the study location. Grasshoppers were gathered utilizing low- and quick sweeps (Brust et al., 2009). It has previously been demonstrated that estimates of grasshopper density obtained using sweep nets vary depending on speed and distance from the ground (Foster & Reuter 1996-1999). Low-and-slow sweeps capture more nymphal grasshoppers and slower moving species, whereas high-and-fast sweeps capture faster moving, more active species (Foster & Reuter 1996-1999).

The species accumulation curve (Figure 4.1) demonstrated that the estimated total species of grasshoppers achieves an asymptote line on the 18th to 20th day of sampling from a total of 20 days, which is sufficient to determine grasshopper species richness and diversity. Based on the graph (Figure 4.1), the graph continues to rise throughout the first week of grasshopper sampling due to an increase in the number of species collected. On the first and second days, the graph begins to climb linearly. The graph approaches a constant value on the third and fourth days, when the cumulative species is 14 samplings, and then increases again from day 5 to day 17 before beginning to reach a constant value. The graph is flat from day 18to day 20 and finally reaches the asymptote line at the end of the day. A species accumulation curve (SAC) that achieves an asymptote shows that the sampling effort was sufficient. On the 18th to 20th day, the SAC curve begins to flatten and approaches the asymptote line, indicatingthat the majority of the grasshopper species in the area have been collected. This means that subsequent sampling attempts may not result in the identification of major new species. A graph that increases throughout the first week of sampling and eventually approaches a constant valueshows that numerous new species were discovered during the initial sample. This growth remained until day 17, when the graph began to flatten between days 18 and 20, hitting the asymptote line. This case demonstrates that a 20-day sampling effort is sufficient to determinethe abundance and diversity of grasshopper species in urban green spaces.

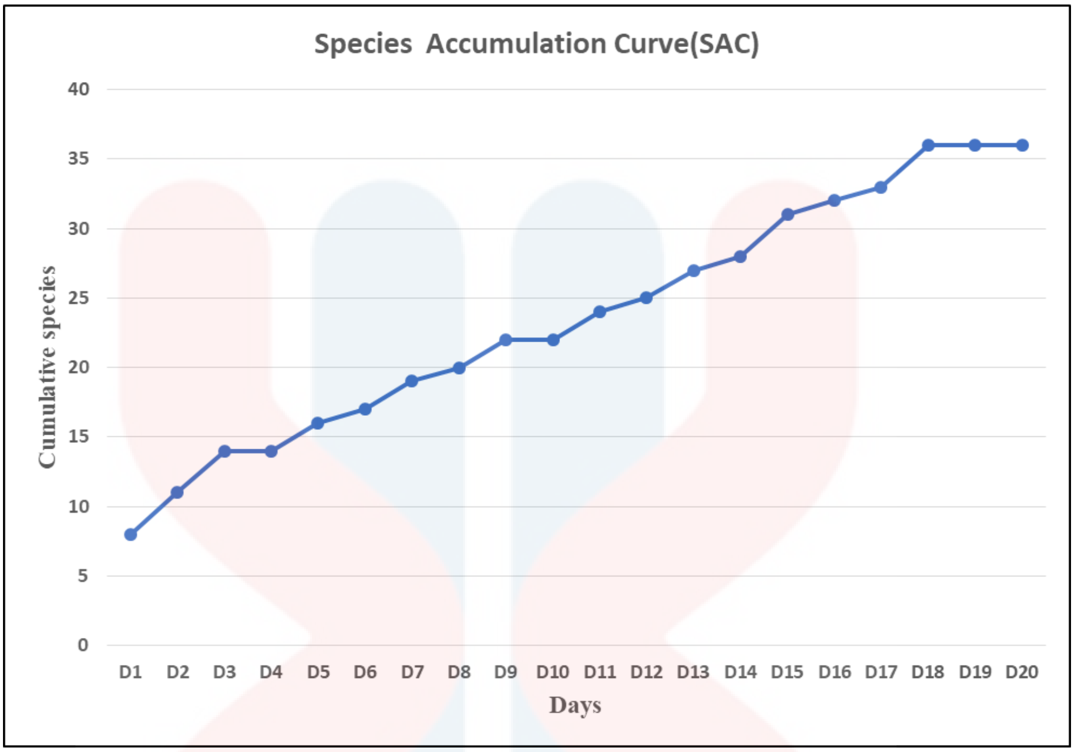

Figure 4.1: Species Accumulation Curve of grasshoppers that has been collected using a sweep netting method in Kg Melor Lama, Kota Bharu, Kelantan.

4.3 Diversity Indices

According to the table (Table 4.2), the Shannon-Wiener Index has a value of 3.30, indicating a consistent environmental state for index diversity and H' value. The higher the value of H, the greater the diversity of species in a given community. Diversity decreases as H decreases. The Shannon-Weaver diversity index typically runs between 1.5 and 3.5, seldom exceeding 4.5. The primary goal of a diversity index is to produce a quantitative measure of biological variability, which may be used to compare biological entities in space or time. In addition, the Simpson diversity index (D) has been recorded as 0.97. The abundance of grasshopper species is primarily owing to the abundance of plants or vegetation in Kota Bharu Kelantan's urban green space, as the diversity of vegetation plays a vital role in the survival of insect fauna by providing food (Aslam, 2009).

A Shannon-Wiener Index of 3.30 indicates a high amount of species variety, implying that the ecosystem is stable and diverse. A high Shannon-Wiener index indicates that the community contains a diverse range of species with reasonably balanced abundances. This suggests a favorable environmental situation that can support a wide range of grasshopper species. The high diversity demonstrates that this ecosystem is diverse and capable of providing a variety of food and habitat for the insect population. This condition is frequently related with environmental stability, as different species and their interactions can assist sustain ecological balance. As a result, a high index value indicates that urban green areas in Kota Bharu, Kelantan, have good environmental conditions for biodiversity and ecosystem stability.

In comparison to the other three families, the Acrididae family has the most species richness (23 species) (Figure 4.2). According to the graph, the Chorotypidae family has the fewest species which is only one species (*Erianthella formosana*), whereas the Tettigoniidae and Pyrgomorphidae families each have ten and two species, respectively.

Table 4.2: Diversity Indices of Grasshopper

Index	Symbol	Total
Shannon-Weiner diversity index	**H'**	**3.30**
Simpson diversity index	**D**	**0.97**

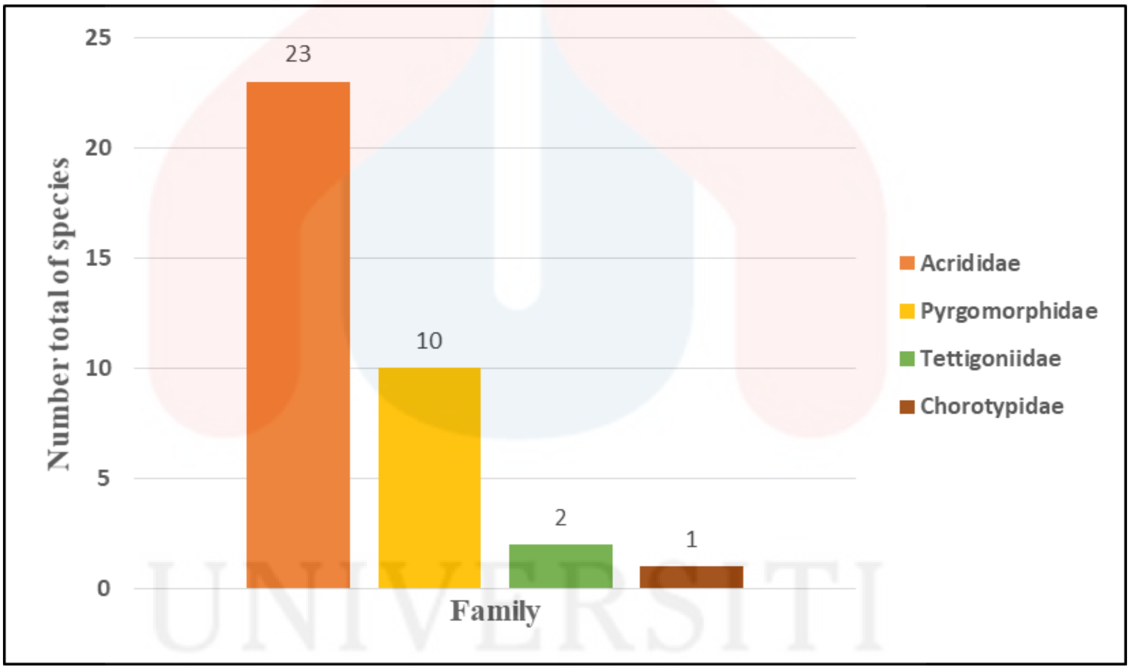

Figure 4.2: Number of species of each family of grasshoppers at urban green areas in Kota Bharu, Kelantan.

4.4 Abundance of Grasshoppers

Species abundance refers to the amount of individuals in a given area. The abundance of each species was determined using the number of individuals (Krishnamurthy, 2003). According to Figure 4.3, the Acrididae family is the most dominant species in this study, with 859 individuals from 23 species, followed by the Tettigoniidae family (88 individuals from 10 species) and the Pyrgomorphidae family (47 individuals from 2 species). Furthermore, Figure 4.3 depicts the smallest number, which is from the Chorotypidae family, with only 5 individuals and one species.

The bar chart shows that the most common species is *Xenocatantops humilis*, which has 97 individuals, followed by *Psophus stridulus* (74) and *Stenocatantops splendens* (69). Several species have modest populations (30-60 individuals), including *Ceracris nigricornis* (53) and *Oedipoda caerulescens* (44). Many species have fewer than 30 individuals, including *Mecopoda elongate*, *Stilpnochlora couloniana* which each have one individual. This shows that some species thrive under favorable conditions, whilst others are rarer and may require conservation efforts to avoid extinction. This is because it could be induced by environmental factors or habitat disturbances. The presence of *Xenocatantops humilis* (97 individuals) shows that this species may have certain ecological preferences or advantages in urban green spaces. One of the primary variables influencing the abundance of these species may be the availability of specific plants that meet their food and habitat requirements. Temperature, humidity, and predator protection, can all help *Xenocatantops humilis* survive and reproduce. Furthermore, the dominance of this species may indicate that they are better adapted to human disturbance or habitat changes than other species. Species with huge populations frequently have adaptable feeding methods and a high tolerance for environmental fluctuation, allowing them to dominate certain habitats. Hence, the abundance of *Xenocatantops humilis* provides an indication of the ecological characteristics of urban green spaces that support the abundance of this species.

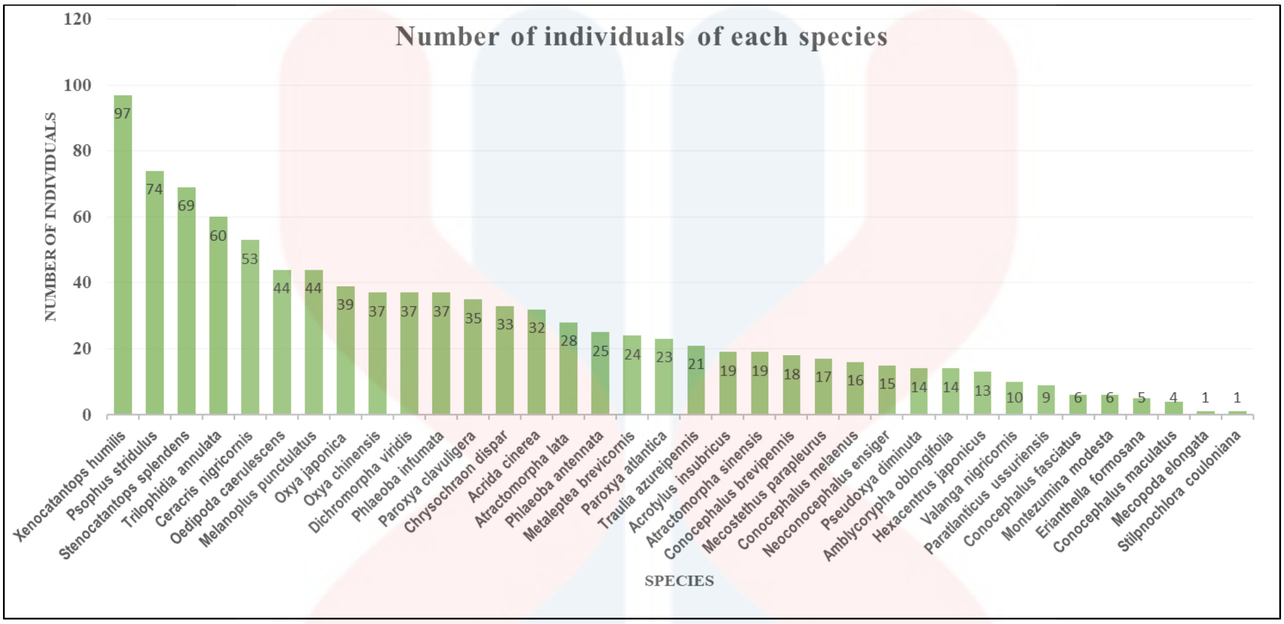

Figure 4.3: Number of individuals of each species grasshoppers at urban green areas in Kota Bharu, Kelantan.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.0 Conclusion

Urban green areas are vegetated areas in urban contexts that provide leisure possibilities while also enhancing biodiversity. The study's findings on the richness and distribution of grasshopper species in urban green spaces are directly related to the overall benefits of urban green spaces, as indicated. The diversity of grasshopper in urban green spaces demonstrates the importance of these sites in maintaining biodiversity, which includes not only plants but also insects and other creatures. According to studies by Joern and Behmer (1998) and Pfadt (2002), urban green spaces with diverse plants can support a diversity of grasshopper species, which in turn provide food and habitat for other predators such as birds and animals. This is consistent with the findings of Gill et al. (2007) that urban green spaces support wildlife and improve air quality through complex ecological processes. Furthermore, research on the link between grasshopper and specific plants in urban green spaces demonstrates that preserving plant diversity in these locations can assist to maintain a balanced and healthy environment. This is consistent with Chiesura's (2004) study, which emphasizes the importance of green areas in improving city quality of life, not just through increased aesthetics and recreational activities, but also through ecological benefits that promote urban residents' well-being.

In this study, a detailed analysis of the diversity of grasshoppers (orthoptera: acridoidea) in urban green areas in Kota Bharu, Kelantan was conducted. The main findings of this study show that the Acrididae family has the most species which is 23, followed by Tettigoniidae (10), Pyrgomorphidae (2), and Chorotypidae which only has one species. For the Shannon- Weiner diversity index, the higher the value of H, the greater the diversity of species in a given community. Diversity decreases as H decreases. Diversity analysis using Shannon-Weiner Diversity Index showed H' Value (3.30). The diversity of grasshoppers in Kota Bharu's urban green areas, with a Shannon-Weiner index (H') of 3.30 and Simpson's index (D) of 0.96, suggests significant species diversity and even distribution. When compared to other Malaysian cities, Kota Bharu exhibits more diversity. For example, Kuala Lumpur has a lower Shannon-Weiner index (H') of 2.85 and Simpson's index (D) of 0.91, indicating less diversity, most likely due to more extensive urbanization (Rahman et al., 2015). Similarly, George Town on Pulau Pinang has a Shannon-Weiner index (H') of 3.10 and a Simpson's index (D) of 0.93, showing higher but somewhat lesser variety than Kota Bharu (Lim et al., 2017). This comparison demonstrates the enormous influence of urban green space management on biodiversity, with Kota Bharu exhibiting especially robust results. Simpson diversity index, and the total diversity (D) of 0.96 indicates that the research area contains a variety of medium to large locust species with a uniform distribution. However, this diversity reflects varying distribution patterns across regions.

Anthropogenic influences can influence the distribution and abundance of grasshopper species in urban green spaces in Kota Bharu, Kelantan. Urbanization, can have a considerable impact on insect populations, including grasshoppers, by affecting water resource availability, soil fertility, and shade. Human activities such as deforestation and development may put strain on these areas, as they do on most tropical forest ecosystems. To ensure the survival of this species, it is critical to preserve its native environment. As a result, protection and conservation measures must be implemented to preserve the long-term survival of the locust species diversity in this region. Infrastructure development, like as road construction and building, and deforestation for agriculture and housing are examples of human activities in Kota Bharu that have an impact on grasshopper biodiversity. Urbanization destroys natural habitats that are essential for grasshoppers survival, limiting their food and shelter supplies. Pollution from industry and home activities can also degrade the quality of soil and water, which are required for locust survival. Several local conservation actions are being implemented to address these challenges. One of these is the urban forest restoration program, which seeks to reintroduce native trees and flora in degraded green spaces. Furthermore, there are initiatives to construct and preserve urban parks and nature reserves that serve as crucial habitats for grasshoppers and others species.

In general, *Xenocatantops humilis* is the most reported species, with 97 individuals among the other species. *Xenocatantops humilis*, also known as the Rufous-legged Grasshopper, is the type species in its genus under the family Acrididae and subfamily Catantopinae, with 69 specimens of *Stenocatantops splendens* recorded. *Stenocatantops splendens* is a grasshopper belonging to the family Acrididae, specifically the subfamily Catantopinae. This implies that the Acrididae family has the most reported grasshopper species. The dominance of one species, such as *Xenocatantops humilis*, can have a substantial impact on the entire grasshopper community. When one species becomes too dominant, it might outcompete others for food and habitat, reducing the number of remaining species. For example, if *Xenocatantops humilis* consumes a large number of plants, it may deplete food resources for other grasshoppers, leading their populations to decline.

Finally, the study's purpose, which was to identify the diversity of grasshoppers (Orthoptera: Acridoidea) in urban green areas in Kota Bharu, Kelantan, was met. Furthermore, study on the abundance of grasshopper species in Kelantan's urban green spaces provides vital information about the region's ecological composition. Using the Shannon-Wiener variety Index and the Simpson Diversity Index to analyze variety and species abundance can help us better understand grasshopper species. During the research of grasshopper variety in Kota Bharu's urban green areas, unexpected obstacles may have included uncovering unexpected species or finding some species more dominant than predicted, such as *Xenocatantops humilis.* Such findings may have an impact on the overall examination of diversity. Unexpected weather changes or human activity, may also influence the outcome. These limitations underscore the importance of continuous monitoring and changes in future studies to better understand and manage grasshopper populations and habitats.

5.1 Recommendation

Further research needs to be done regarding the diversity of locusts in Malaysia to compare the diversity and distribution of different species of locusts that are still found in Malaysia, especially in urban green areas like in Kelantan. For additional research on grasshopper diversity in Malaysia, urban green areas like as Putrajaya, which has huge parks and a diverse range of plants, and Penang Hill, with its rich forest environment, could be appropriate sites. Both sites have a diverse range of plants and ecosystems, which can help researchers learn about grasshopper diversity and dispersion. Research in this area can help us learn more about how grasshopper species adapt to diverse urban contexts, as well as increase awareness about the need of biodiversity conservation in urban green spaces. The variety of grasshoppers with beautiful colors and patterns can attract people's interest with the uniqueness of the grasshopper itself so that it can encourage and attract people to learn and appreciate our nature. In addition, researchers need to use other techniques that are effective in locust sampling such as using trap techniques or larger trap nets so that many species of grasshopper can be caught as well as study and analyze more carefully and in detail the appropriate time to carry out the process of catching locusts, which is as in night time . This is because the vision of insects such as grasshoppers is limited at night and grasshoppers are also not very active at night. In addition, urban green areas have high potential in other studies related to the study of species such as cockroaches, crickets, dragonflies, butterflies, and other plant species. In addition, the behavior and environment of grasshopper needs to be studied in depth to know the different behavior of each species. The vast urban green area has the potential to obtain more species of flora and fauna for further study in increasing the diversity of species including grasshoppers. Practical efforts can be made to protect existing green spaces in Kota Bharu while also creating new ones. First, protect and restore existing green spaces by monitoring and preventing pollution and limiting urban development. Besides, plan and carry out new green projects, such as tree planting and the establishment of new urban parks, using a variety of plant species to increase biodiversity and also engage the community in initiatives that raise awareness and educate them about the value of green area, as well as promote sustainable activities like trash reduction and recycling. These actions will assist to protect and extend habitats for grasshoppers and other species, as well as improve the city's quality of life.

In addition, to enhance grasshopper diversity (Orthoptera: Acridoidea) in urban green areas in Kota Bharu, Kelantan, it is proposed that a variety of habitats that support different grasshopper species be established and maintained. This includes protecting existing green spaces, establishing new ones, and connecting them to facilitate species migration and genetic exchange. Planting a varied range of native flora can provide valuable resources and microhabitats for various grasshopper species. Furthermore, reducing pesticide use and preserving green spaces in accordance with ecological principles will contribute to the maintenance of a healthy, balanced ecosystem. Public knowledge and community involvement in conservation activities can help to increase biodiversity and sustainable urban development initiatives. Several dynamic tactics can be used to raise public awareness and encourage community participation in conservation efforts. Host interesting workshops and seminars on the importance of biodiversity and urban green spaces, customized to different age groups. Organize engaging activities like immersive tree-planting programs, transformative habitat restoration projects, and captivating guided nature excursions to invigorate the community. Develop strong ties with local schools, companies, and community organizations to promote collaborative conservation programs and initiatives. These initiatives can instill a strong community commitment to sustainable development and ecological preservation.

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APPENDIX A

Images of selected grasshoppers that has been collected and preservation from urban green area in Kota Bharu, Kelantan.

Family Pyrgomorphidae

Atractomorpha lata

Family Acrididae

Valanga nigricornis

Family Tettigoniidae

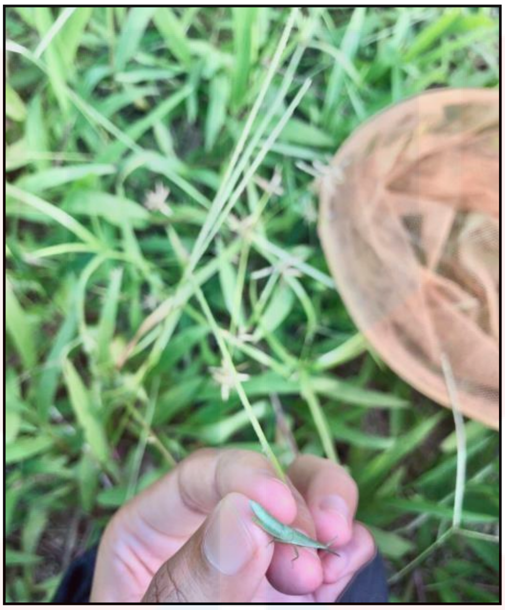
Mecopoda elongate

Grasshopper were pin on the polystyrenes board.

Grasshopper were pinned to a polystyrene board and stored in a refrigerator for preservation

APPENDIX B

Image of one of grasshopper from different family caught using a sweep net



Family: Pyrgomorphidae

Atractomorpha lata

APPENDIX C

A number of species, individual and Shannon-Wiener diversity index of a grasshoppers in urban green area in Kota Bharu, Kelantan.

Species	N	pi	ln pi	pi*ln pi
Oxya japonica	39	0.039039	-3.24319	-0.12661
Oxya chinensis	37	0.037037	-3.29584	-0.12207
Atractomorpha lata	60	0.06006	-2.81241	-0.16891
Trilophidia annulata	44	0.044044	-3.12257	-0.13753
Oedipoda caerulescens	74	0.074074	-2.60269	-0.19279
Psophus stridulus	69	0.069069	-2.67265	-0.1846
Stenocatantops splendens	97	0.097097	-2.33204	-0.22643
Paratlanticus ussuriensis	33	0.033033	-3.41025	-0.11265
Conocephalus melaenus	14	0.014014	-4.2677	-0.05981
Conocephalus brevipennis	37	0.037037	-3.29584	-0.12207
Xenocatantops humilis	44	0.044044	-3.12257	-0.13753
Chrysochraon dispar	37	0.037037	-3.29584	-0.12207
Pseudoxya diminuta	53	0.053053	-2.93646	-0.15579
Dichromorpha viridis	23	0.023023	-3.77126	-0.08683
Melanoplus punctulatus	25	0.025025	-3.68788	-0.09229
Phlaeoba infumata	19	0.019019	-3.96232	-0.07536
Conocephalus fasciatus	32	0.032032	-3.44102	-0.11022
Ceracris nigricornis	35	0.035035	-3.35141	-0.11742
Paroxya atlantica	17	0.017017	-4.07354	-0.06932
Phlaeoba antennata	24	0.024024	-3.7287	-0.08958
Acrotylus insubricus	21	0.021021	-3.86223	-0.08119
Acrida cinerea	15	0.015015	-4.1987	-0.06304
Hexacentrus japonicus	10	0.01001	-4.60417	-0.04609
Paroxya clavuligera	28	0.028028	-3.57455	-0.10019
Erianthella formosana	19	0.019019	-3.96232	-0.07536
Mecostethus parapleurus	9	0.009009	-4.70953	-0.04243
Metaleptea brevicornis	16	0.016016	-4.13417	-0.06621
Traulia azureipennis	18	0.018018	-4.01638	-0.07237
Neoconocephalus ensiger	6	0.006006	-5.115	-0.03072
Atractomorpha sinensis	13	0.013013	-4.34181	-0.0565
Amblycorypha oblongifolia	14	0.014014	-4.2677	-0.05981
Montezumina modesta	6	0.006006	-5.115	-0.03072
Valanga nigricornis	1	0.001001	-6.90675	-0.00691
Mecopoda elongata	1	0.001001	-6.90675	-0.00691
Stilpnochlora couloniana	4	0.004004	-5.52046	-0.0221
Conocephalus maculatus	5	0.005005	-5.29732	-0.02651
TOTAL	999	1	-142.959	-3.29694

APPENDIX D

Number of species, individual and Simpson diversity index of a grasshoppers in urban green area in Kota Bharu, Kelantan.

Species	N	n-1	N(n-1)
Oxya japonica	39	38	1482
Oxya chinensis	37	36	1332
Atractomorpha lata	60	59	3540
Trilophidia annulata	44	43	1892
Oedipoda caerulescens	74	73	5402
Psophus stridulus	69	68	4692
Stenocatantops splendens	97	96	9312
Paratlanticus ussuriensis	33	32	1056
Conocephalus melaenus	14	13	182
Conocephalus brevipennis	37	36	1332
Xenocatantops humilis	44	43	1892
Chrysochraon dispar	37	36	1332
Pseudoxya diminuta	53	52	2756
Dichromorpha viridis	23	22	506
Melanoplus punctulatus	25	24	600
Phlaeoba infumata	19	18	342
Conocephalus fasciatus	32	31	992
Ceracris nigricornis	35	34	1190
Paroxya atlantica	17	16	272
Phlaeoba antennata	24	23	552
Acrotylus insubricus	21	20	420
Acrida cinerea	15	14	210
Hexacentrus japonicus	10	9	90
Paroxya clavuligera	28	27	756
Erianthella formosana	19	18	342
Mecostethus parapleurus	9	8	72
Metaleptea brevicornis	16	15	240
Traulia azureipennis	18	17	306
Neoconocephalus ensiger	6	5	30
Atractomorpha sinensis	13	12	156
Amblycorypha oblongifolia	14	13	182
Montezumina modesta	6	5	30
Valanga nigricornis	1	0	0
Mecopoda elongata	1	0	0
Stilpnochlora couloniana	4	3	12
Conocephalus maculatus	5	4	20
TOTAL	999	963	43522