DIVERSITY AND SPECIES RICHNESS OF INSECTIVOROUS BIRDS IN AGRICULTURAL LANDSCAPES OF UNIVERSITI MALAYSIA KELANTAN JELI CAMPUS.

by

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A report submitted in fulfillment of the requirements for the degree of Bachelor of Applied Science (Natural Resources Science) with Honours

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DECLARATION

I declare that this thesis entitled "Diversity and Species Richness of Insectivorous Birds in Agricultural Landscapes of Universiti Malaysia Kelantan Jeli Campus" is the result of my research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature : Aslan

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Date : 08 AUGUST 2024

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DIVERSITY AND SPECIES RICHNESS OF INSECTIVOROUS BIRDS IN AGRICULTURAL LANDSCAPES OF UNIVERSITI MALAYSIA KELANTAN JELI CAMPUS.

ABSTRACT

Insectivorous birds are birds that feed primarily on insects and other arthropods. They play an important role in the ecosystem as natural pest controllers and indicators of environmental health and biodiversity. This study aims to calculate the diversity index and species richness of insectivorous birds in the agricultural landscapes of Universiti Malaysia Kelantan Jeli Campus from February to March 2024. Kelantan is experiencing a hot and dry season during this period, which is affecting the presence of birds. In the study, 27 sampling plots, each 100 meters apart with a radius of 20 meters, were selected to evaluate the diversity of insectivorous bird species using mist nets and point counts. Binoculars and a field guide were utilized to aid in the identification process. To predict and analyse the diversity within these plots, several diversity indices were employed, including Shannon's Index, which measures species diversity, Margalef's Richness Index, which assesses species richness, and Pielou's Evenness Index, which evaluates how evenly individuals are distributed across different species. Additionally, ANOVA (Analysis of Variance) was used to compare the means of diversity indices across different plots, providing a comprehensive understanding of the bird species diversity in the study area. In the study, 15 species of insectivorous birds from 10 families were recorded, totaling 604 individuals in the agricultural landscape. The Muscicapidae family represented the highest percentage of recorded families, accounting for 27.81% of the total. Using the Shannon-Wiener Index (H'), the study revealed that the commercial crops area close to the forest exhibited higher bird diversity (H' = 2.29) compared to areas dedicated to fruits (H' = 2.18) and vegetables (H' = 2.14). These findings highlight the diverse community of insectivorous birds present in the agricultural landscapes of Universiti Malaysia Kelantan Jeli Campus. The study emphasizes the importance of habitat diversity in supporting avian biodiversity and suggests that maintaining a variety of crop types could enhance ecological health and pest control services.

Keyword: Insectivorous bird, mist nets, point counts, ANOVA,

KEPELBAGAIAN DAN KEKAYAAN SPESIES BURUNG INSEKTIVOUS DALAM LANDSKAP PERTANIAN UNIVERSITI MALAYSIA KELANTAN KAMPUS JELI.

ABSTRAK

Burung insektivor adalah burung yang memakan serangga dan artropod lain sebagai makanan utama mereka. Mereka memainkan peranan penting dalam ekosistem sebagai pengawal perosak semulajadi dan indikator kesihatan alam sekitar serta kepelbagaian biodiversiti. Kajian ini bertujuan untuk mengira indeks kepelbagaian dan kekayaan spesies burung insektivor di lanskap pertanian Kampus Jeli, Universiti Malaysia Kelantan dari Februari hingga Mac 2024. Kelantan sedang mengalami musim panas dan kering dalam tempoh ini, yang mempengaruhi kehadiran burung. Dalam kajian ini, 27 plot pensampelan, setiap satu berjarak 100 meter dengan radius 20 meter, dipilih untuk menilai kepelbagaian spesies burung insektivor menggunakan jaring kabus dan pengiraan titik. Teropong dan panduan lapangan digunakan untuk membantu dalam proses pengecaman. Untuk meramalkan dan menganalisis kepelbagaian dalam plot-plot ini, beberapa indeks kepelbagaian telah digunakan, termasuk Indeks Shannon yang mengukur kepelbagaian spesies, Indeks Kekayaan Margalef yang menilai kekayaan spesies, dan Indeks Keseimbangan Pielou yang menilai sejauh mana individu diedarkan secara merata di kalangan spesies yang berbeza. Tambahan pula, ANOVA (Analisis Varians) digunakan untuk membandingkan min indeks kepelbagaian di antara plot yang berbeza, memberikan pemahaman yang menyeluruh tentang kepelbagaian spesies burung di kawasan kajian. Dalam kajian ini, 15 spesies burung insektivor dari 10 keluarga telah direkodkan, dengan jumlah keseluruhan 604 individu di lanskap pertanian. Keluarga Muscicapidae mewakili peratusan tertinggi daripada keluarga yang direkodkan, merangkumi 27.81% daripada jumlah keseluruhan. Menggunakan Indeks Shannon-Wiener (H'), kajian ini mendapati bahawa kawasan tanaman komersial yang berdekatan dengan hutan menunjukkan kepelbagaian burung yang lebih tinggi (H' = 2.29) berbanding kawasan yang dikhususkan untuk buah-buahan (H' = 2.18) dan sayur-sayuran (H' = 2.14). Penemuan ini menekankan komuniti burung insektivor yang pelbagai yang hadir di lanskap pertanian Kampus Jeli, Universiti Malaysia Kelantan. Kajian ini menekankan kepentingan kepelbagaian habitat dalam menyokong biodiversiti burung dan mencadangkan bahawa mengekalkan pelbagai jenis tanaman dapat meningkatkan kesihatan ekologi dan perkhidmatan pengawalan perosak.

Kata kunci: Burung pemakan serangga, Jaring kabut, Kiraan titik, Analisis Varians

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LIST OF ABBREVIATIONS

GPS	Global Positioning System
IUCN	International Union for Conservation of Nature
LC	Least Concern
NFT	Nutrient Film Technique
NRE	Natural Resources and Environment Ministry
SAC	Species Accumulation Curve
UMK	Universiti Malaysia Kelantan

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Birds exhibit functional diversity across dietary, foraging, and microhabitat niches, performing essential roles such as pollination, seed dispersal, and predation (Tscharntke et al., 2008). Malaysia is one of the most biodiverse countries in the world, hosting about 10% of the global bird species (NRE, 2009). Malaysia remains one of the most biodiverse countries, with significant efforts to protect its ecosystems (NRE, 2020). The bird fauna of Malaysia is influenced by the geographic, climatic, and historical factors that shape the distribution and diversity of the habitats and ecosystems in the country. Malaysia is situated near the center of Southeast Asia, at 1-7 degrees north and 100-119 degrees east. It includes the 11 states of the southern segment of the Thai-Malay Peninsula, commonly referred to as West Malaysia, and the two Bornean States of Sabah and Sarawak, also referred to as East Malaysia or Malaysian Borneo. It covers a total land area of 330,803 km2. Malaysia has a largely equatorial climate. The entire region is hot and humid, with little annual variation in temperature. Recorded temperatures typically hover at 25-34C in the lowlands and 17-22C in the mountains. Rainfall is abundant and frequent, typically exceeding 2,000 mm per year.

Malaysia is blessed with a wide range of environments such e.g. forests, open areas, shrublands, wetlands, lakes rivers, ponds of aquaculture, woodlands, agricultural lands, paddy fields, and areas of water treatment (Rajpar & Zakaria, 2011) that area rich in avian diversity, including 862 species, 167 migrants, 18 endemic species (Avibase 2024) and 76 threatened (IUCN, 2019).

Lowland forests are the most extensive and diverse habitat for birds in Malaysia, covering about 60% of the land area (Habitats & Infrastructure, 1974). Regarding the extent of lowland forests, recent data from the Global Forest Resources Assessment (FRA, 2020) indicates that Malaysia's forest cover is approximately 59.5% of the total land area. The lowland dipterocarp forests, which are among the most biodiverse, have been significantly impacted by logging and agricultural activities. Lowland forests are defined as forests below 900 m elevation and can be classified into dipterocarp forests, peat swamp forests, and freshwater swamp forests. Lowland forests have a complex structure, consisting of several layers of vegetation, such as emergent trees, canopy, subcanopy, understorey, and ground. Lowland forests are home to more than 260 bird species, belonging to different families and feeding guilds. However, these habitats are under threat from human activities, such as deforestation, land conversion, urbanization, pollution, hunting, and climate change. The current conservation measures are in place in Malaysia to protect bird species in lowland forests and agricultural landscapes including sustainable forest management, protection of important areas for birds, forest restoration and replanting, and law enforcement while conservation to protect bird species in agricultural landscapes including promotion of environmentally friendly agricultural practices such as planting local fruit trees and reducing the use of pesticides can preserve the diversity of bird species. These threats pose serious challenges for the conservation and management of the bird species in Malaysia, especially the endemic and endangered ones such as the Helmeted Hornbill (*Buceros vigil*), Straw-crowned Bulbul

(*Pycnonotus zeylanicus*), Wrinkled Hornbill (*Rhabdotorrhinus corrugatus*), Steppe eagle (*Aquila nipalensis*), and Greater Green Leafbird (*Chloropsis sonnerati*).

Agricultural landscapes are the second most common habitat for birds in Malaysia, covering about 20% of the land's area (Nur Munira Azman et al., 2011). Universiti Malaysia Kelantan Jeli Campus has various types of agricultural landscape such as fruits (pineapple, durian, rambutan, banana), vegetables (chili, eggplant, cucumber, corn), and commercial crop areas (agarwood, rubber tree, palm oil tree). different areas will affect the presence of insectivorous bird species in certain areas. Agricultural landscapes are defined as areas where human activities, such as cropping, livestock, and aquaculture, modify the natural vegetation and soil. Agricultural landscapes can be classified into different types, such as paddy fields, oil palm plantations, rubber plantations, orchards, and mixed farms. Agricultural landscapes have different management practices, such as irrigation, fertilization, pesticide use, and crop rotation. The study area is an agricultural area under the management of Agro Techno Park UMK. Cultivation of certain vegetable crops using the NFT (Nutrient Film Technique) method and fertigation system is practiced at Agro Techno Park UMK (2021). Although important for plant growth, it can have an indirect effect on insectivorous birds. The excessive use of fertilizers disrupts the population and diversity of insects in agricultural areas. Agricultural landscapes provide concentrated food resources for birds, such as grains, seeds, fruits, green vegetation, insects, rodents, and arthropods (Cannor and Shrub, 1986). However, agricultural landscapes also pose various risks and challenges for birds, such as habitat loss, fragmentation, degradation, predation, and poisoning. However, agricultural landscapes also pose various risks and challenges for birds, such as habitat loss, fragmentation, degradation, predation, and poisoning.

This study focused on the diversity index and species richness of insectivorous birds in the agricultural landscapes of Universiti Malaysia Kelantan Jeli Campus. This research was conducted to add more information about the diversity index and species richness of insectivorous birds in agricultural landscapes. The point count and mist net are a methodology used to achieve research objectives. This research has potential in the conservation and management of insectivorous birds in agricultural landscapes in the future.

1.2 Problem Statement

Insectivorous birds are the birds that feed primarily on insects and other arthropods. They play an important role in the ecosystem as natural pest controllers, as well as indicators of environmental health and biodiversity. Since they are sensitive to habitat change and birds are the ecologist's go-to tool. Next, based on the findings of Gallina et al. (2005), it is evident that bees exhibit rapid responses to different external stimuli. This characteristic enables honey bees to serve as effective indicators for monitoring and assessing environmental quality. The presence of bees in an agricultural region is indicative of the area's overall health. The main problem that will be addressed by this study is the need for more data and knowledge about the composition of insectivorous bird species in the agricultural landscape of UMK Jeli Campus. Why this lack of data is critical for local conservation efforts. This study was conducted to find out the species and abundance of insectivorous birds, a comparison of the diversity of insectivorous birds between fruit and vegetables, and commercial crop areas. Next, agricultural practices such as pesticide use and crop diversity affect the diversity of insectivorous birds.

1.3 Objective

The objectives of this research are:

I. To conduct an insectivorous bird survey using point counts and mist nets in the agricultural landscapes of Universiti Malaysia Kelantan Jeli Campus from February to Mac 2024.

II. To calculate the diversity index and species richness of insectivorous birds in the agricultural landscapes of Universiti Malaysia Kelantan Jeli Campus from February to Mac 2024.

1.4 Scope of Study

This study focused on identifying species of insectivorous birds that will be conducted in the agricultural area of Universiti Malaysia Kelantan (UMK) Jeli Campus (101°51′15″ to 101°53′15″ E and 5°43′15″ to 5°45′30″ N, 1.09265 km2). The agricultural area consists of various crops, such as fruit trees (durian, rambutan, water guava, mango, pineapple), vegetables (chili, cucumber, corn, eggplant), and commercial crops (oil palm, rubber, agarwood). The data collection was carried out for a month, from February to Mac 2024. A total of twenty-seven-point counts and six mist nets were used to survey the bird species and abundance in the study area. The diversity of insectivorous birds will be recorded in the book, Bird of Malaysia, and Singapore.

1.5 Significant of Study

This study focused on identifying species of insectivorous birds that was conducted in the agricultural area of Universiti Malaysia Kelantan (UMK) Jeli Campus (101°51′15″ to 101°53′15″ E and 5°43′15″ to 5°45′30″ N, 1.09265 km2). The agricultural area consists of various crops, such as fruit trees (durian, rambutan, water guava, mango, pineapple), vegetables (chilli, cucumber, corn, eggplant), and commercial crops (oil palm, rubber, agarwood).

The data collection was carried out for a month, from February to Mac 2024. A total of twenty-seven-point counts and five mist nets were used to survey the bird species and abundance in the study area.

The study is limited by the spatial and temporal variation of the bird and insect populations influenced by habitat types, availability of food resources, human activity, environmental conditions, and the availability and accessibility of the study site. This study is expected to provide benefits to insectivorous bird species such as increasing their conservation status, increasing their ecological role, and increasing public awareness and appreciation of them. The findings of this research are very important and required as an additive for enhancing the wildlife management system, and policy maker and at the same time as the material to improve the promotion of ecotourism.

This study also benefits the agricultural sector such as reducing pest damage and pesticide use, increasing crop yield and quality, and promoting sustainable agricultural practices. The expected benefits of the study for society, such as improving health and environmental balance, supporting food security and sovereignty, and fostering human-wildlife coexistence.

CHAPTER 2

LITERATURE REVIEW

2.1 Classification of Insectivorous Birds

Insectivorous birds are birds that feed primarily on insects and other arthropods, which constitute a major part of their diet (Mansor et al., 2018)

Insects are an essential protein source for many birds, especially during the breeding season and the nestling stage. Insects also provide other nutrients, such as fats, vitamins, and minerals, that are vital for the growth and survival of birds. Insects are diverse and abundant in various habitats, such as grasslands, forests, and wetlands, and include a wide variety of taxa, such as winged insects, aquatic insects, grasshoppers, caterpillars, dragonflies, butterflies, and many others (Wigglesworth, 2019).

Insectivorous birds are widespread and diverse, comprising about 60% of the global bird species (Sherry, 2021). They occupy different habitats and niches and exhibit different morphological, behavioral, and physiological adaptations to their diet. For instance, some insectivorous birds feed from the air, such as swifts and swallows, while others feed from the ground, such as thrushes and plovers. Some insectivorous birds have long, pointed bills, such as woodpeckers and kingfishers, while others have short, rounded bills, such as warblers and tits. Some insectivorous birds are migratory, such as flycatchers and cuckoos, while others are resident, such as wrens and nuthatches (Greenberg, 1995).

Insectivorous birds are vulnerable to various human-induced threats, such as habitat loss and fragmentation, climate change, pesticide use, and hunting. These threats can reduce the availability and quality of food resources, alter the ecological interactions and processes, and increase the mortality and extinction risk of insectivorous birds. In particular, tropical insectivorous birds are more sensitive and susceptible to these threats, due to their high specialization and endemism (Sherry, 2021).

Despite the importance and diversity of insectivorous birds, their diet in agricultural landscapes, which are increasingly replacing natural habitats in Malaysia, is poorly understood. This poses a challenge for the conservation and management of these birds, as well as for the sustainable development of the agricultural sector. The main research question that this study will address is: How does the diet of insectivorous birds in agricultural landscapes of UMK Jeli Campus compare with the diet of insectivorous birds in lowland forests? This question will be answered by conducting a bird survey and diet analysis in both habitats and by comparing the results using various methods and variables (Sridhar et al. 2012; Karr et al. 2017).

2.2 Habitat Preferences of Insectivorous Birds

Insectivorous birds are an important part of the ecology, and their habitat requirements have been thoroughly researched. according to Ding Li Yong et al., (2011) studied the effects of habitat fragmentation on tropical bird populations. They used timed point counts to collect lowland forest birds on six land-bridge islands and two mainland forest locations in Lake Kenyir, Peninsular Malaysia. According to the findings, insectivorous birds are the worst impacted guild. Insectivorous birds were identified as the dietary guild most vulnerable to fragmentation, followed by frugivorous and omnivorous birds. Insectivorous bird assemblages were visibly depauperate on artificial forest islands in Lake Kenyir, which is consistent with Neotropical Forest fragmentation research. The study found that preserving predator-prey interactions in lowland tropical forests will require the survival of entire groups of insectivorous bird guilds in Malaysia.

Furthermore, an observation-based study by (Sherry, 2021) investigated the influence of habitat fragmentation on tropical bird populations. They discovered that insectivorous birds are the most severely affected guild. According to the study, the extinction of insectivorous birds might have a huge influence on the environment.

The findings emphasise the need of preserving intact groups of insectivorous bird guilds in order to preserve predator-prey interactions in lowland tropical forests.

2.3 The Biogeography and Diversity of Insectivorous Birds

The biogeography and diversity of insectivorous birds are shaped by various environmental factors, such as temperature, precipitation, and vegetation, that affect the availability and distribution of food resources, habitats, and competitors. One of the most influential factors is temperature, which affects the metabolism, activity, and survival of both insects and birds. For example, Jetz et al., (2012) found that temperature was the main predictor of the global distribution and diversity of insectivorous birds, with most species occurring in warm and wet regions, such as the tropics and the subtropics.

Another example is Sherry (2021) who predicted that climate change would reduce the diversity and abundance of insectivorous birds in the tropics, due to the increased temperature and drought stress, and the decreased insect availability and quality. Another important factor is precipitation, which affects the moisture, productivity, and seasonality of the ecosystems. For example, Sridhar et al., (2012) found that precipitation was the main driver of the seasonal variation of insectivorous bird diversity and abundance in a tropical forest in India, with more species and individuals during the wet season than the dry season.

Another example is Karp et al., (2018) who found that precipitation was the main determinant of the spatial variation of insectivorous bird diversity and abundance in the Amazonian rainforest, with more species and individuals in the wetter and more productive regions than the drier and less productive regions. A third factor is vegetation, which affects the structure, complexity, and diversity of the habitats and the food resources. For example, Wells (1999) found that vegetation was the main factor influencing the vertical stratification of insectivorous bird diversity and abundance in a lowland forest in Malaysia, with different species and feeding guilds occupying different layers of the forest, such as canopy, understory, and ground.

Another example is Barbaro et al., (2017) who found that vegetation was the main factor affecting the landscape heterogeneity of insectivorous bird diversity and abundance in an agricultural landscape in France, with more species and individuals in the more diverse and complex habitats, such as hedgerows, woodlots, and orchards, than the more homogeneous and simple habitats, such as crops and grasslands.

2.4 The Factors and Variables That Affect the Diet of Insectivorous Birds

The diet of insectivorous birds is influenced by various factors and variables, both biotic and abiotic, that affect the availability and quality of food resources, as well as the feeding preferences and strategies of the birds. Some of the most important factors and variables are habitat, season, competition, and predation. For example, habitat affects the diet of insectivorous birds by determining the type, diversity, and abundance of insects and other arthropods in different ecosystems, such as forests, grasslands, wetlands, and agricultural landscapes. Habitat also affects the diet of insectivorous birds by providing different structures and microhabitats for foraging, such as canopy, understory, ground, and water. Another example is predation, which affects the diet of insectivorous birds by imposing a trade-off between food intake and predation risk, and by shaping the anti-predator behavior and morphology of the birds. Predation also affects the diet of insectivorous birds by regulating the population dynamics and interactions of the birds and their prey, as well as of their predators and competitors.

2.5 Diet of Insectivorous Bird

Insectivorous birds are an essential aspect of the ecology because they manage bug populations. According to Kéry et al., (2018), insectivorous birds devour 400-500 million metric tons of prey every year. The research also shows that birds in forests consume more than 70% of the world's yearly prey intake of insectivorous birds, whereas birds in other biomes such as savannas and grasslands, croplands, deserts, and Arctic tundra contribute less.

Another research (Mansor et al., 2018) gives a comprehensive investigation of the stomach contents of various insectivorous birds. The research discovered that the diet of insectivorous bird’s changes based on species and season. Tropical insectivorous birds in the lowland Malaysian rainforest, for example, eat mostly Coleoptera (53%), Hymenoptera (19%), Blattodea (11%), and Araneae (11%). The research also discovered that nutritional variances may be attributable to changes in bill shapes and sizes, which correlate to prey size.

2.6 The Ecological and Economic Roles and Impacts of Insectivorous Birds

Insectivorous birds have various ecological and economic roles and impacts, both positive and negative, on the ecosystems and the human societies they inhabit. One, that they consume large amounts of insects and other arthropods that can damage crops, forests, and human health. For example, Sekercioglu et al., (2017) estimated that insectivorous birds provide a global pest control service worth about $149 billion per year, by reducing crop losses and pesticide use.

Another example is Whelan et al., (2015) who found that insectivorous birds reduced the herbivory and increased the growth and survival of oak trees in a forest experiment. , by feeding on seeds, fruits, and grains, and by causing physical damage to the plants. For example, Ali (1971) reported that insectivorous birds, such as sparrows, weavers, munias, starlings, and mynas, caused significant losses to rice, wheat, millet, and sorghum crops in India.

Another example is Nyffeler et al., (2018) who found that insectivorous birds, such as drongos, shrikes, and raptors, preyed on beneficial insects, such as honeybees, butterflies, and ladybugs, in oil palm plantations in Malaysia. Besides pest control and crop damage, insectivorous birds can also have other ecological and economic roles and impacts, such as seed dispersal, pollination, tourism, and recreation. For example, Sekercioglu (2006) showed that insectivorous birds, such as hornbills, barbets, and woodpeckers, dispersed the seeds of many fruiting plants in tropical forests, and enhanced the forest regeneration and diversity. Another example is Barbaro et al., (2017) who suggested that insectivorous birds, such as trogons, woodpeckers, and spiderhunters, pollinated the flowers of many plants in agricultural landscapes, and increased the crop yield and quality.

2.7 Importance of Insectivorous Birds in the Agricultural Landscape

Insectivorous birds play a vital role in agroecosystems by delivering a variety of ecosystem services that enhance agricultural productivity. These birds have been seen feeding on a broad range of insects, including agricultural pests, minimizing the requirement for chemical pesticides (Peisley et al., 2015). Furthermore, insectivorous birds play a significant role in pollination and seed dissemination, which is critical for preserving biological diversity in agricultural environments (Sherry, 2021).

Insectivorous birds have been demonstrated in studies to have a major influence on crop yields. Research on a coffee field in India, for example, discovered that the presence of insectivorous birds enhanced coffee yields by up to 36%. Similarly, another research in rice fields in China discovered that insect-eating birds decreased pest numbers by up to 70%, resulting in improved crop yields (Nyffeler et al., 2018).

However, the advantages of insectivorous birds extend beyond their influence on agricultural production. These birds also offer other ecosystem services, such as disease prevention and minimizing the demand for artificial fertilizers (Peisley et al., 2015). Furthermore, insectivorous birds play a vital role in the food chain, supplying food for other creatures such as snakes and mammals (Peisley et al., 2015).

Insectivorous birds confront several dangers in agricultural environments, despite their value. Bird populations are declining due to a variety of issues including habitat loss, pesticide usage, and climate change (Peisley et al., 2015). To guarantee that insectivorous birds continue to provide ecosystem services, conservation measures that safeguard their habitats and decrease the use of toxic pesticides in agriculture must be implemented (Peisley et al., 2015).

2.8 The Conservation and Management of Insectivorous Birds

The conservation and management of insectivorous birds are crucial for the maintenance and restoration of the ecosystem functions and services, as well as for the biodiversity and cultural values that these birds provide. However, insectivorous birds face various threats and challenges, both natural and anthropogenic, that endanger their survival and diversity. Some of the main threats and challenges are habitat loss and fragmentation, climate change, pesticide use, and hunting. For example, Sodhi et al., (2004) reported that habitat loss and fragmentation were the main causes of the decline and extinction of insectivorous bird species in Southeast Asia, due to the conversion of natural habitats, such as forests and wetlands, into agricultural and urban landscapes.

Another example is Whelan et al., (2008) who reported that pesticide use was the main cause of the reduction and contamination of food resources and habitats for insectivorous birds, due to the direct and indirect effects of chemical substances on insects and birds. To address these threats and challenges, various opportunities and strategies can be implemented, both at the local and global scales, and both at the individual and collective levels, to protect and enhance the insectivorous bird populations and communities.

Some of the main opportunities and strategies are habitat restoration and conservation, climate change mitigation and adaptation, integrated pest management, and public education and awareness. For example, Wells (2007) suggested that habitat restoration and conservation were the main strategies for the protection and enhancement of insectivorous bird diversity and abundance in Malaysia, by creating and maintaining suitable habitats, such as forest corridors, buffer zones, and green spaces, in both natural and agricultural landscapes.

Another example is Connor & Shrub (1986) who suggested that integrated pest management was the main strategy for the protection and enhancement of insectivorous bird roles and impacts in agricultural systems, by reducing the pesticide use and increasing the crop diversity, and by encouraging and supporting the natural pest control service provided by insectivorous birds.

CHAPTER 3

METHODOLOGY

3.1 Study Area

The study was conducted in the agricultural area of Universiti Malaysia Kelantan (UMK) Jeli Campus (101°51′15″ to 101°53′15″ E and 5°43′15″ to 5°45′30′ N, 1.09265 km2). Availability and accessibility have been reasons to be considered before choosing a study site. The agricultural area of the UMK Jeli campus, which is close to the student residential college and is easy to access, is the reason for making it the study site. Besides that, the study area has various types of agricultural plants providing food sources and encouraging predator-prey interactions. The study lasted for 20 days. All bird surveys were conducted by a single observer to eliminate the potential differences capacity among observers between 0700 and 1100 and set up five mist nets in each plot at a distance of 100 m from each other when there is no rain or strong wind started at 7:00 am until 7:00 pm. The study covers the entire agricultural area of fruits, vegetables, and commercial crops. In addition, the diversity of bird species and crops such as fruits, vegetables, and commercial crops available at the study site makes it easier to achieve the objectives of the study.

The UMK Jeli Campus is located in a lowland dipterocarp forest, which is characterized by the dominance of dipterocarp tree species and a high biodiversity of flora and fauna. The site has a tropical climate, with daily temperatures ranging from 23°C to 33°C. The site receives an average annual rainfall of about 2000 mm, with the wettest months being September to December and March to May. This study was focused on the agricultural area of Agro Techno Park and the student company farm at UMK Jeli, which are part of the campus. This research used the sampling techniques mist net and point counts. The agricultural area consists of various types of crops, such as fruit trees (durian, rambutan, water guava, mango, pineapple), vegetables (chili, cucumber, corn, eggplant), and commercial crops (oil palm, rubber, agarwood).

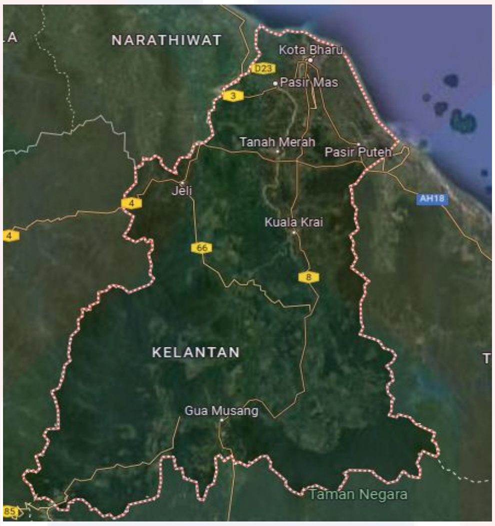

Figure 3.1: Map of Kelantan State (Source: Google Map, 2024)

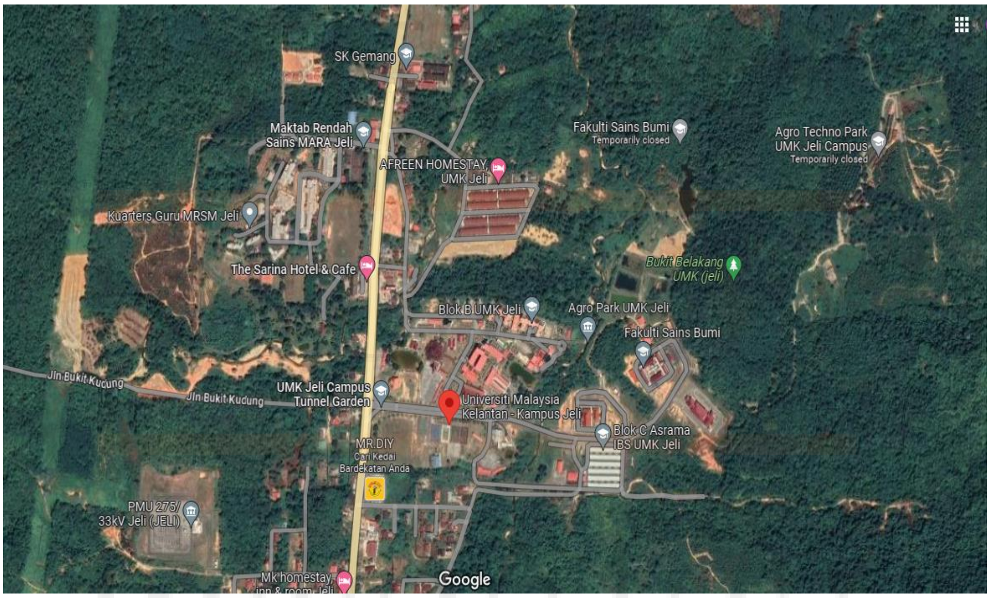

Figure 3.2: Map of University Malaysia Kelantan Jeli Campus

(Source: Google Maps, 2024).

3.2 Material

The materials that were used in the research study consisted of the materials for fieldwork, specifically for sampling and storing the collected samples. Table 1 presents a list of the primary materials used

Table 3.1: List of materials

Equipment/Apparatus	Description
Mist net	It was used to capture the birds.
Global Positioning System (GPS)	It was used to record the coordinates of the sampling plots.
Glove	They were used to protect the hands.
Binocular	It was used to observe the birds.

3.3 Method

3.3.1 Collection of Insectivorous Bird

In this study, mist nets and point counts were used to achieve the first objective of the study. According to Aainaa (2023), point count is used in the majority of bird monitoring studies. Point counting is used to record a diverse range of birds, including "shy" species. This approach is the simplest and most consistent way to count birds in the research area from time to time.

Mist nets are also a popular technique for capturing birds for scientific study. Mist nets were created by Japanese hunters over 300 years ago to catch birds for food (Austin, 1947). This method is a popular technique for collecting birds to study demographic and population factors.

To cover the large agricultural area, 27 sampling plots were selected, each 100 m apart with a radius of 20 m from each other. The sampling plot is determined based on the selected. Factors influencing this selection include the availability of food and an easily accessible location. A large radius may be able to gather the maximum amount of information, but differences in the landscape from one survey point to the next can make it difficult for researchers to set a radius. Therefore, to avoid bias, the researcher used a 20-meter radius throughout the study. In addition, perform a point count in each plot by recording the number and identity of insectivorous birds seen or heard within a 20-meter radius for 10 minutes. Binoculars and a field guide were used for this purpose. The researcher repeated the survey for each plot every day throughout the study period.

Next, the researcher set mist nets in each plot at a distance of 100 m from each other when there is no rain or strong wind to catch insectivorous birds flying or foraging in the area. The selection of the mist net location in each plot is based on the point count plot. The researcher used a nylon net with a size of 2 x 9 m and 36 mm mesh. The researcher also conducted a mist net inspection every hour from 7:00 am to 7:00 pm with five plots every day. The birds trapped in the mist nets were handled carefully and placed in a cloth bag to calm them down and reduce stress. Captured birds were released again after identification. The researcher repeated the point count and mist nets in each plot if the data were insufficient.

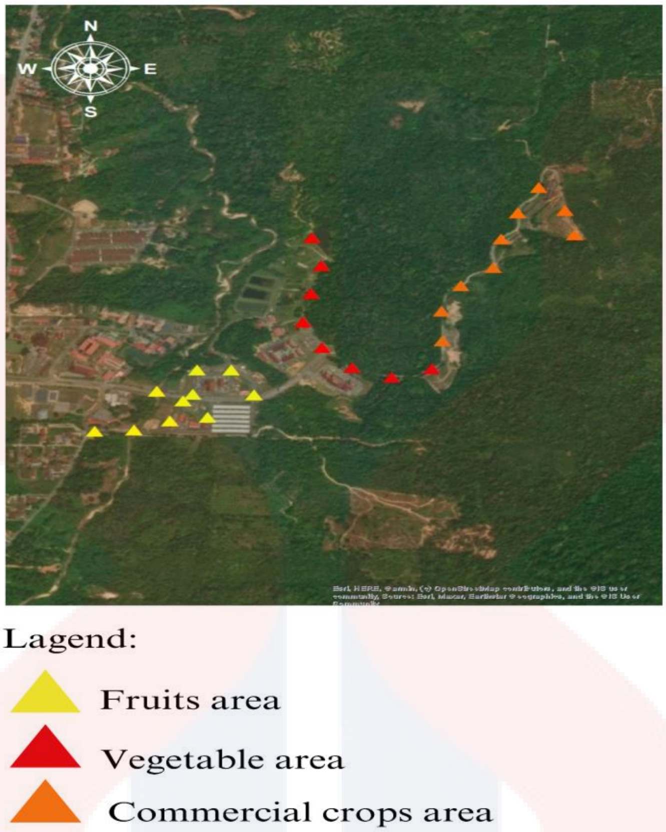

Figure 3.3: A total of 27 sampling points at the agricultural landscape with at least 100m intervals.

3.3.2 Species Identification

Species identification was an essential step for this study. The identification of insectivorous birds was conducted while in the field. Unidentifiable species should be listed by taxonomic merger. In addition, note the general characteristics of the birds observed in the Additional Notes section, such as size, perching location, colour, beak shape, and behaviour. The identification of insectivorous birds trapped in a mist net was also carried out to confirm that they were insectivorous. Species identification is based on criteria and characteristics to identify the sex and species of a bird, such as plumage, size, shape, beak, voice, and behavior. The field guide used for bird species identification is "Birds of Malaysia and Singapore" by Seng et al. (2020).

3.4 Data Analysis

Several types of diversity indices are required to predict the diversity of insectivorous bird species. The indexes are Shannon's Index, Margalef's Richness Index, Pielou's Evenness Index, and ANOVA. The Shannon- Weiner Index (H'), also called Shannon's diversity index, is another popular measure of biodiversity or species diversity in each area (Bollarapu & Ramarao., 2021). The Shannon-Weiner Index was used to measure the diversity of insectivorous bird species between the different types of crops, such as fruit trees, vegetables, and commercial crops.

The equation of this calculation:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

where:

H' = Shannon Diversity Index

pi = The proportion of individuals belong to species

S = Total number of species

Magalef's Richness Index was used to calculate the species richness of insectivorous birds in each plot.

The equation of this calculation:

Margalef's index (d) = (S – 1) / In (N)

S = total number of species

N = total number of individuals in the sample

In = natural logarithm

Pielou's Evenness Index was used to measure the relative abundance of insectivorous bird species between the different types of crops, such as fruit trees, vegetables, and commercial crops.

The equation of this calculation:

$$J' = H' / In\ (S)$$

Where:

H'= Shannon's Diversity Index

S = Total number of species in a sample

In= Natural logarithm

To compare the species richness, abundance, and diversity of insectivorous birds between different types of crops, ANOVA Tests were employed. Initially, a researcher used ANOVA to compare the means of insectivorous birds between the different types of crops. The equation of this calculation:

$$F = \frac{MSB}{MSE}$$

Whare:

F= Ratio, which is used to determine whether there are significant differences between the means of two or more groups.

MSB= Mean square between which is calculated by dividing the sum of squares between by the degrees of freedom between.

MSE= Mean square error, which is calculated by dividing the sum of squares error by the degrees of freedom error.

The researcher visualized the study's results using graphs and tables, such as pie charts and bar charts, and then interpreted and discussed the findings. The results of this study reflect a study by Khairul Bahar (2020), who used data analysis such as Shannon's Index, Margalef's Richness Index, Pielou's Evenness Index, and Relative Abundance and conducted a study entitled Diversity and Species Richness of resident birds at Lata Keding and Bukit Kudung, Jeli Kelantan.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Bird Diversity

4.1.1 Bird Families

From this study, 15 species of insectivorous birds from 10 families were recorded to have 604 individuals in the Agricultural Landscape of University Malaysia Kelantan Jeli Campus in 2024. The main methods of sampling birds' species were recorded through mist netting, direct observation, and point count. The study period starts in February and ends in March, depending on weather conditions. The sampling was conducted for 20 days, from 7:00 a.m. to 7:00 p.m. Sampling is done in designated areas, such as fruit, vegetable, and commercial crop areas. Based on Figure 4.1 the highest percentage of recorded families was Muscicapidae accounting for 27.81%.

The highest percentage of bird families recorded was Muscicapidae (Oriental Magpie-Robin and Asian Brown Flycatcher). Another family with higher observation was Pycnonotidae (24.34%), which is only represented by three species (Yellow-Vented Bulbul, Asian Red-Eyed Bulbul, and Black-Headed Bulbul). Besides, Cisticolidae (2 individuals), Alcedinidae (14 individuals), and Cuculidae (15 individuals) families had the least observation with only under 20 individuals recorded in this study. Family Cisticolidae, which comprises Yellow-bellied Prinia and family Alcedinidae consists of White-throated Kingfisher, followed by family Cuculidae with three species of Greater Coucal, Asian Koel, and Green-billed Malkoha.

All species presented in the present research were identified as species of "Least Concern" or LC according to the IUCN Red List of Threatened Species. Despite their current status in "Least Concern," or LC, pollution, habitat destruction, disturbance, and changes in land use pose a threat and cause a decline in the population of insectivorous bird species. Table 4. 1 lists the bird families that were observed in this study according to their respective orders.

The Muscicapidae family, sometimes known as the Old-World flycatchers, is a large and varied group of songbirds that includes over 135 species. Species can be found in a variety of habitats, including forest, woodland, savanna, grassland, the borders of water bodies and wetlands, grazing and other agricultural regions, well-vegetated gardens, and residential areas. Old World flycatchers utilize a range of feeding strategies to hunt insects and other arthropods. Based on observations made during sampling, Magpie Robin searches for insects in the pineapple, chili, and eggplant areas with its partner. Magpie robins typically hunt insects in low-ground areas. Most species hunt for flying insects from an exposed vantage point, such as a high perch on a tree, and then catch them in an airborne pursuit. Some species also eat by scavenging food off bark, branches, foliage, or spider webs, or by swooping down to feast on arthropods found on the ground.

The Pycnonotidae family (Passeriformes, suborder Oscines) is a group of small to medium-sized birds that are primarily found in tropical regions. The majority of bulbuls reside in forests, while a small number inhabit open land or tree-covered vegetation. The majority of species can adapt to man-made environments, particularly gardens, and are found in open territory with dispersed trees and vegetation. However, a few species are restricted to woodland (Keith,1992).

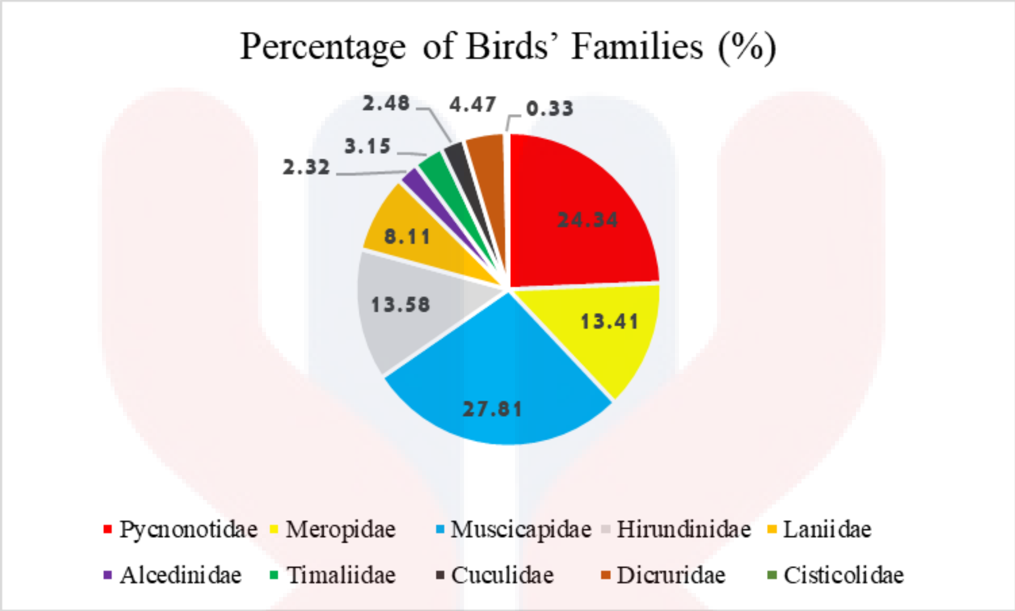

Figure 4.1: The percentage of Birds' Families

Table 4.1: List of bird's families with frequency of observation

No	Family	Number of Species	Frequency of Observation
1	Pycnonotidae	3	147
2	Meropidae	1	81
3	Muscicapidae	2	168
4	Hirundinidae	1	82
5	Laniidae	1	49
6	Alcedinidae	1	14
7	Timaliidae	1	19
8	Cuculidae	3	15
9	Dicruridae	1	27
10	Cisticolidae	1	2
	Total	15	604

In Malay, the Magpie Robin is commonly referred to as Murai Kampung (Asyraf et al., 2015). It is a diminutive passerine bird and a favoured aviary bird in the Muscicapidae (Old World Flycatchers) family. The habitat of this species comprises villages, plantations, gardens, and parks in Peninsular Malaysia, as well as offshore islands. It is typically observed hunting for insects on the ground in pairs or solely, jumping from one location to another (Strange & Jeyarajasingam, 1993; Jeyarajasingam & Pearson, 2012).

Next, in Malay, the Asian Brown Flycatcher is locally referred to as Sambar Asia (Asyraf et al., 2015). This species is recognized as inhabiting a diverse array of habitats, including forest fringes, open wooded coastal areas, and mangrove areas. It is also frequently situated in gardens and parks (Strange & Jeyarajasingam, 1993; Jeyarajasingam & Pearson, 2012). This subspecies breeds in Myanmar to northern Malaya and migrates to the Malay Peninsula during winter (Jeyarajasingam & Pearson, 2012). The characteristics include the drab grey-brown upperparts, whitish underparts, faint grey-brown upper breast, and distinctive eye ring.

The Yellow-vented Bulbul (*Pycnonotus goiavie*r) belongs to the bulbul family of passerine birds. It is the most abundant of all bulbuls and may be found in a wide range of open environments, but rarely in dense woods. Yellow-vented Bulbuls consume berries and tiny fruits. In addition to nectar, it consumes new shoots and insects. This species has brown upperparts, a chalky white head, a black crown, and dark lines around the eyes. The underparts are white, with a slight mottled brownish-grey on the breast and pale yellow undertail coverts (Strange & Jeyarajasingam, 1993).

Merops leschenaulti is a small bee-eater that is around 20 cm in length. Because of its chestnut-coloured head, neck, and upper back, it is also known as a

Chestnut-Headed Bee-Eater. It also has a yellow neck with a black band below (Strange & Jeyarajasingam, 1993) and a green tail. During flight, you can see the iridescent, pale blue rump. The crown, neck, and upper back of its youngsters are all green. Chestnut-headed bee-eaters may be found from India to southern China, as well as throughout Southeast Asia to Java and Bali. This species may be found in open areas with scattered trees, beach scrubs, plantations, and lowlands up to lower mountain heights. It searches the air for insects.

Figure 4.2: Oriental Magpie-Robin (*Copsychus saularis*) from the Muscicapidae family.

4.1.2 Relative Abundance and Species Composition

According to Gatesire et al. (2014), we can determine that the relative abundance of birds is very important as this variable indicates the proportion of the existing population in a habitat. The relative abundance of a certain species of bird can therefore be used to determine the conservation status of that particular species. Relative abundance is calculated by dividing species by the total number of individuals in a given region or sample. According to Rajpar and Zakaria (2011), a species' relative abundance is generally connected to its vegetation community, food resource availability, and habitat structure. This indicator is useful for indicating the rarity of a species in a community. To determine the health of natural ecosystems, species composition is an extremely important factor.

The most often observed species in the fruit are the Oriental Magpie-Robin (*Copsychus saularis*) at 20.13% relative abundance, followed by the Yellow-Vented Bulbul (*Pycnonotus goiavier*) at 15.44% and the Barn Swallow (*Hirundo rustica*) at 14.09%. The vegetable area had the highest species recorded as the Oriental Magpie-Robin (*Copsychus saularis*) with a relative abundance of 19.51%, followed by the Barn Swallow (*Hirundo rustica*) at 17.07% and the Yellow-Vented Bulbul (*Pycnonotus goiavier*) at 15.24%. The commercial crop area is dominated by Oriental Magpie-Robin (*Copsychus saularis*) and Yellow-Vented Bulbul (*Pycnonotus goiavier*), which make up 16.20% and 14.10% of the species present, respectively.

It is noteworthy to observe that certain birds, like bulbuls, prefer to spend their time in the open canopy as opposed to the dense forest undergrowth and in the canopy, layer as opposed to the closed ground layer. The habitat selection of insectivorous bird species in the agricultural landscape at UMK Jeli Campus is determined based on the frequency and absence of insectivorous birds and frequency and abundance factors. In addition, survey insectivorous bird food sources and assess the impact on human activities.

Figure 4.3: Oriental Magpie-Robin (*Copsychus saularis*)

Figure 4.4: Yellow-Vented Bulbul (*Pycnonotus goiavier*)

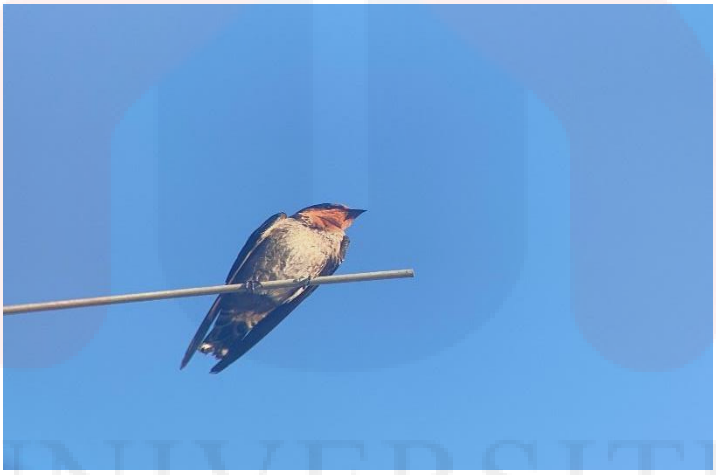

Figure 4.5: Barn Swallow (*Hirundo rustica*)

Fourteen species of insectivorous birds have been observed in commercial agriculture areas. There are 11 species identified in the fruit area and 12 in the vegetable section. The White-throated Kingfisher species (*Halcyon smyrnensis*) was exclusively observed in the fruit area. Citing Jeyarajasingam et al, (2012), then the White-throated kingfisher was a bird that did not depend much on water and availed itself of different habitats such as agricultural tracts, paddies, and gardens. Based on the above results it can be concluded that the White-throated kingfisher was considered as a generalist species, meaning that they are able at certain times to adjust to given changes in the environment and diet flexibility. The white-throated kingfisher (Halcyon smyrnensis) has a broad diet and can adapt to a variety of environments, unlike specialist species with more restricted habitats or nutritional requirements. The white-throated kingfisher feeds on a diverse range of food, including insects, tiny reptiles, amphibians, small mammals, and other birds. This nutritional versatility enables them to survive in a wide range of settings, including woods, grasslands, wetlands, agricultural regions, and even cities. Unlike certain specialist species, such as the Chestnut-Headed Bee-Eater (Merops leschenaultii), which rely entirely on specific insects and environments. Table 4.2 documents all species of birds along with their relative abundance.

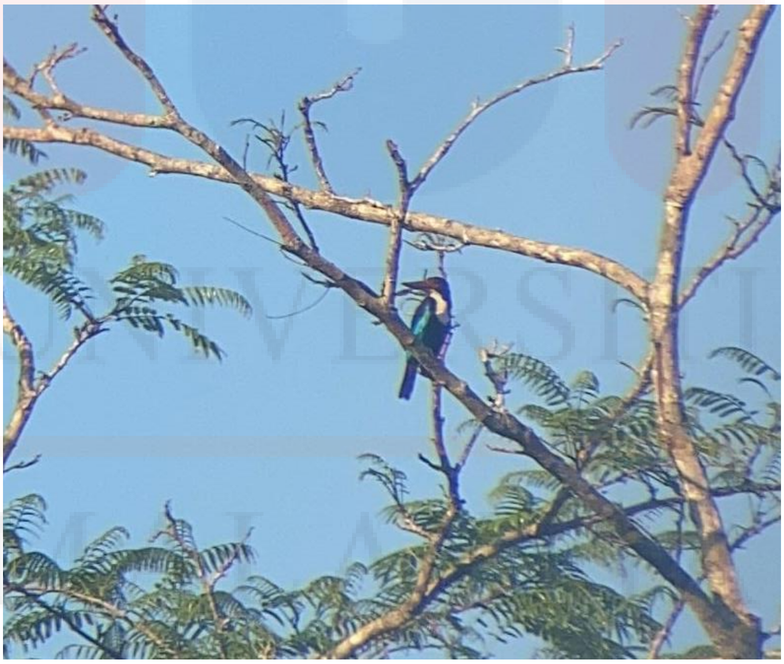

Figure 4.6: White-throated Kingfisher (*Halcyon smyrnensis*)

Table 4.2: Relative abundance of insectivorous birds in fruits, vegetables and commercial crop areas.

Scientific Name	Common Name	Fruits	Vegetable	Commercial Crop
Pycnonotus goiavier	Yellow-Vented Bulbul	15.44	15.24	16.20
Merops leschenaultii	Chestnut-Headed Bee-Eater	13.42	12.20	14.10
Copsychus saularis	Oriental Magpie-Robin	20.13	19.51	16.20
Hirundo rustica	Barn Swallow	14.09	17.07	11.30
Lanius cristatus	Brown Shrike	10.07	8.54	6.90
Pycnonotus brunneus	Asian Red-Eyed Bulbul	4.70	7.32	6.50
Muscicapa dauurica	Asian Brown Flycatcher	8.72	8.54	11.00
Halcyon smyrnensis	White-throated Kingfisher	9.40	-	-
Pycnonotus atriceps	Black-Headed Bulbul	1.34	2.44	2.70
Macronous gularis	Pin-Stripped Tit-Bubbler	1.34	0.61	5.50
Centropus sinensis	Greater Coucal	1.34	3.05	2.10
Dicrurus paradiseus	Greater Racket-Tailed Drongo	-	4.88	6.50
Prinia flaviventris	Yellow-bellied Prinia	-	0.61	0.30
Eudynamys scolopaceus	Asian Koel	-	-	0.30
Phaenicophaeus tristis	Green-billed Malkoha	-	-	0.30

As mentioned above, two species of insectivorous birds only recorded in commercial crops were Asian Koel (*Eudynamys scolopaceus*) and Green-billed Malkoha (*Phaenicophaeus tristis*) but at 0.30% relative abundance. Commercial plant areas have various species of trees including rubber trees, agarwood, and others, which is a factor in the presence of species of Green-billed Malkoha in this area. Green-billed Malkoha (*Phaenicophaeus tristis*) in commercial crop areas is linked to several ecological and environmental factors. commercial agriculture near the forest serves as an alternative habitat for the Green-billed Malkoha bird. Green-billed Malkoha respond to moderate levels of disturbance in commercial agricultural areas where human activity is less prevalent. Other agricultural landscape areas, on the other hand, are affected by human activities. Trees or tall plants in commercial crops provide a good platform for hunting and foraging. According to Lim et al. (2020), this species is recognised as inhabiting a diverse array of habitats, including primary, logged, and secondary forests, second growth, cultivation (e.g. rubber), and adjacent gardens from lowlands and hills to 1,200m.

Figure 4.7: Green-billed Malkoha (*Phaenicophaeus tristis*) only recorded in commercial crops.

4.1.3 Bird Diversity Index

Diversity indexes provide a much better understanding of the community structure than simple species counts: they take into account the proportion of species in the community as well. In addition to versions, the density and uniformity of species in a community are also expressed in diversity indexes. Shannon- Weiner Index (H'), also called Shannon's diversity index is another popular measure of biodiversity or species diversity in each area (Bollarapu & Ramarao., 2021). It measures the richness and patterns of species occurrence in a particular region or a population. This measure was put forward by Claude Shannon and Warren Weaver in the year 1949 which is derived from information theory and was developed from the concept of uncertainty. The greater the diversity index of an ecosystem, the more stable it is; conversely, the lower the index, the less stable the ecosystem (Kachare et al. 2011).

A total of 604 individuals representing 15 species, 13 genera, and 10 families were documented in this study. Data on the total number of families, genera, and resident species obtained from this study are summarized in Figure 4.3 for three types of areas. The Shannon-Wiener Index (H') also reflects higher diversity for commercial crops area compared to fruits and vegetables area (commercial crops: H' = 2.29; fruits: H' = 2.18; vegetables: H' = 2.14). Insectivorous species in commercial agricultural regions at UMK Jeli had a higher Shannon-Wiener index, indicating a diversified and balanced natural predator community. This has significant ramifications for agriculture. Increased insectivorous species numbers serve to naturally manage pest populations and reduce agricultural damage. This increase reduces dependency on insecticides. A wide range of insectivorous species helps to improve overall biodiversity and ecological health. It promotes a healthy food chain and contributes to environmental stability. This indicates that the vegetable area represents a loss of avifaunal diversity. The area of vegetable crops close to the IBS residential college and the administrative office of UMK Jeli is a factor in the presence of insectivorous birds because birds are exposed to human activities and noise.

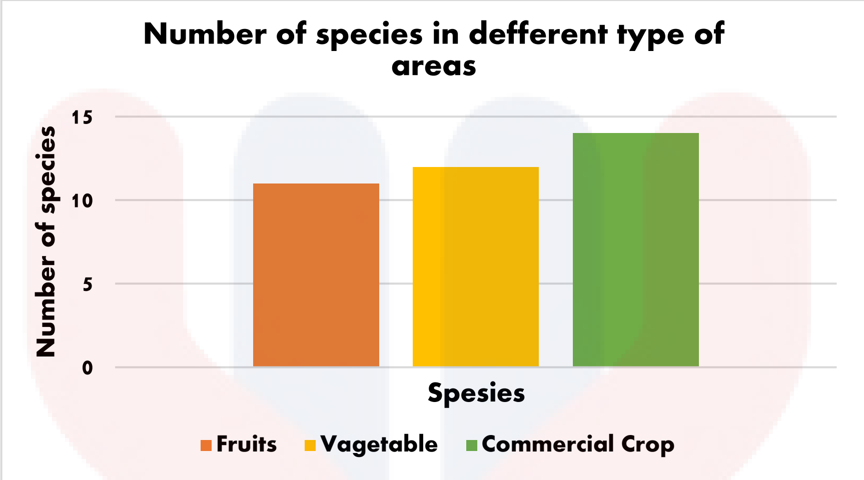

Figure 4.8: Number of species for fruits, vegetables, and commercial crops areas.

The Margalef's Richness Index (R_1) of resident species discovered in the fruit region was 2.00, the vegetables area was 2.16, and the commercial crops were 2.29 (Table 4.3). The Margalef index assesses species richness and is strongly dependent on sample size. According to Davari, Jouri, and Ariapour (2011), the value of Margalef richness is variable and has no limit due to the number of species available. Thus, it is commonly used to compare places or durations (Turkmen & Kazanci, 2010). The position of commercial crops close to the forest is a factor in the presence of insect-eating birds. Forest areas near farm areas are habitats that offer many sources of food, water and shelter for bird species (Krisanti et al. 2017). In addition to providing food, a wide variety of plants gives birds cover from predators and inclement weather. They may also be used as building materials, a perch for territory monitoring, a location to sing to attract mates, and a means of marking territory.

The Pielou evenness index (J') can be described as moderate even because it ranges from 0 to 1. The complete even, with an evenness value of 1, indicates that every species in the sample have the same number of individuals. In this study, the Pielou evenness index (J') was recorded (fruits: J' = 0.89; vegetables: J' = 0.88;

commercial crops: J' = 0.87). This suggests that while commercial crops are the most species-rich and diverse, fruits exhibit a more balanced distribution of species. The distribution of bird species in a given area is mostly determined by climatic conditions (Welty, 1962). According to Radford & du Plessis (2003), weather conditions have an impact on body temperature regulation, food availability, and the energy required to fly. The timing of nesting and the quantity of eggs laid are two indicators of how birds react to variations in the weather.

Table 4.3: Bird species richness (s), the absolute number of birds observed (N), Shannon-Wiener Index (H'), Margalef's Richness Index (R1), and evenness indices (J')

Areas	s	N	H'	R_1	J'
Fruits	11	149	2.14	2.00	0.89
Vegetables	12	164	2.18	2.16	0.88
Commercial Crops	14	291	2.29	2.29	0.87

The summary statistics show that Fruit has an average of 7.45 with a variance of 4.997, Vegetable has an average of 8.2 with a variance of 3.853, and Commercial crop has a much higher average of 14.55 with a variance of 20.471. The ANOVA Table 4.4 reveals that the between-group variation has a sum of squares (*SS*) 4.5) of 608.63, degrees of freedom (*df*) of 2, and a mean square (*MS*) of 304.32, resulting in an F-value of 31.136. The within-group variation has an SS of 557.1, df of 57, and an MS of 9.774. The total SS is 1165.73 with 59 degrees of freedom.

The critical F-value (F crit) is 3.159, and the calculated F-value (31.136) far exceeds this, indicating significant differences between group means. Additionally, the P-value is extremely small (7.26E-10), which is much lower than the common significance level of 0.05, further supporting that the differences between the groups are statistically significant. Therefore, we reject the null hypothesis that the means of the three groups are equal, concluding that the type of crop whether Fruit, Vegetable, or Commercial crop significantly affects the measured variable. An ANOVA can demonstrate differences in the abundance and distribution of insectivorous bird species based on different types of area. If the ANOVA results show significant differences, it indicates that certain areas may have higher or lower numbers of certain bird species, which may be due to factors such as food availability and human disturbance. Areas with higher bird diversity and abundance may be critical habitats that need protection, whereas areas with lower populations may require restoration efforts.

Table 4.4: Sum of Square (*SS*), degrees of freedom (*df*), mean square (*MS*), F-value (*F*), and the critical F-value (*F crit*)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	608.6333333	2	304.3166667	31.136331	7.26E-10	3.158842719
Within Groups	557.1	57	9.773684211			
Total	1165.733333	59				

4.1.4 Species Accumulation Curve

Species accumulation curves are observed when survey effort is increased in a specific sampling area. According to Moreno and Halffter (2000), species accumulation curves (SAC) are a useful tool for assessing the effectiveness and comprehensiveness of species inventories. SAC can also be used to compare surveys that follow standardized sampling techniques. Furthermore, Species accumulation curves can be utilized to estimate the minimal amount of sampling required to achieve a suitable degree of comprehensiveness in a survey, as determined by the proportion of species discovered in the area. This can lead to improved planning and sampling techniques.

Regarding the SAC in Figure 4.5, the graph reaches an asymptote at the final sampling point, indicating that all species of insectivorous birds recorded in this study are accounted for. When an asymptote is reached, it suggests that the amount of sampling done is adequate. The asymptote is observed at the point where the horizontal curve represents the minimal effort needed to obtain a dependable estimate of species richness in the given area. Nevertheless, approaching an asymptote does not automatically ensure the detection of all species. Certain avian species with timid behaviour can be challenging to observe due to their effective concealment. Despite increasing effort, it may still be insufficient to harvest this species effectively. Seasonal variations can influence the abundance of bird species. Moreover, the efficacy and partiality of the sampling technique can impact the Species Accumulation Curve (SAC), since various approaches may be better suited for detecting specific bird species.

However, this study necessitates ongoing monitoring due to the presence of multiple variables that can impact the outcomes including food availability, predators, disturbance of human activities, weather, and land use ab This occurs because of the phenomenon of migration in certain species, whereas other species have distinct periods for reproduction or non-reproduction. Various factors, such as fluctuations in bird distribution and abundance over different seasons, time, and climate can have an impact on the result.

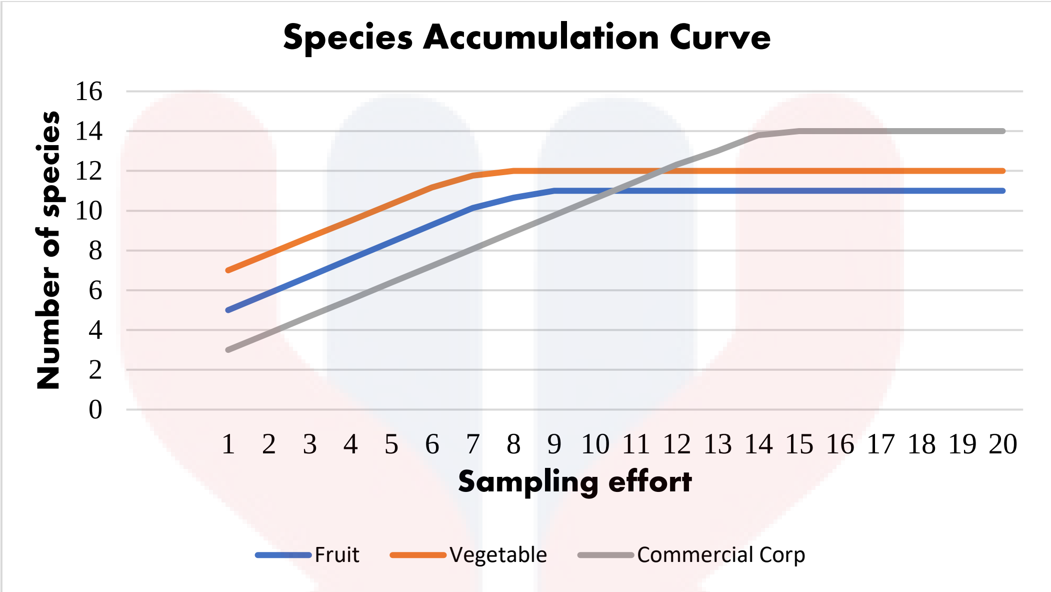

Figure 4.9: The Species Accumulation Curve.

4.1.5 Faecal sample

It's intriguing to note that the accidental collection of insectivorous bird fecal samples, although not the primary focus of the study, offers valuable insights into the diversity of insect species within the agricultural landscapes of Universiti Malaysia Kelantan Jeli Campus. These findings underscore the interconnectedness between avian populations and insect abundance, highlighting the potential role of insectivorous birds as indicators of ecosystem health in agricultural settings. Additionally, the identification of insect orders such as Hymenoptera, Odonata, Orthoptera, and Coleoptera within bird droppings provides concrete evidence of the diverse array of prey available to these avian species. This strengthens the argument for incorporating avian monitoring as a complementary tool in agricultural management strategies aimed at promoting biodiversity conservation and sustainable farming practices.

The diversity of insect species provides a food source for insectivorous birds. Faecal samples were found when White-throated Kingfisher (*Halcyon smyrnensis*) were caught in the net. The faecals are then taken to the laboratory to be identified. Research indicates that bird droppings contain the orders Hymenoptera, Odonata, Orthoptera, and Coleoptera. This is demonstrated by the detection of fragments of legs, wings, abdomen, antennae, thorax, and head. It can be concluded that the study area has a diversity of insect species. The distribution of birds is mostly influenced by physical or abiotic variables. However, the amount of physiological tolerance to a certain environment is also influenced by interactions such as predation and competition (Rabenold & Bromer, 1989).

Figure 4.10: The leg order of Orthoptera

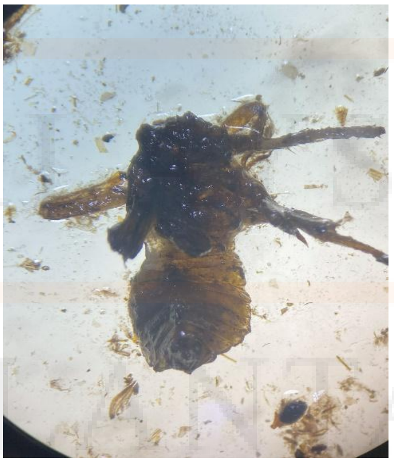

Figure 4.11: Order Hymenoptera

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Overall, the point count and mist net installation met the study's main objectives, which were to calculate the diversity index and species richness of insectivorous birds in the agricultural landscapes of the Universiti Malaysia Kelantan Jeli Campus from February to March 2024. 604 birds from 15 different families have been identified. Many variables impact the diversity and number of birds in the study which factors were most influential including food availability, migration, and human activities. The findings of this study show that point count and mist net are popular strategies for recording bird diversity. The significance of the Muscicapidae and Pycnonotidae families is evident in the presence of a robust ecosystem characterised predator-prey interactions. In agricultural environments, the existence of insectivorous birds can have substantial consequences for pest control. These avian species play a vital role in ecological pest management by consuming insects that harm agricultural produce, so potentially diminishing the reliance on synthetic pesticides.

The findings suggest that agricultural landscapes including components of natural ecosystems have the capacity to sustain greater biodiversity, especially insectivorous bird species. Therefore, farmers and land managers can enhance bird diversity and ecosystem services by adopting agroforestry practices that integrate trees and shrubs into crop production systems, preserving natural habitats near farmland, minimizing pesticide usage, and advocating for organic farming methods.

5.2 RECOMMENDATION

From this study, the agricultural landscape area can accommodate a variety of insectivorous and other bird species. The area is suitable to be made into a habitat area because of the availability of food and the variety of plants that catalyse the increase in the number of birds such as rubber trees, agarwood, and vegetables. As a result, the Agro Techno Park must plan the systematic development and selection of plants and insecticides to maintain ecosystem balance. for example, not using insecticides that harm birds and pollute the environment, such as Neonicotinoids disrupt the nervous systems of birds, affecting their foraging ability, reproduction, and survival, which can lead to population declines and pollution of soil and water (Gibbons et al., 2015). For the sampling method, increase the installation of mist-netting and the addition of plot point counts throughout the study period to maximise the findings of the study on bird species in the study area.

REFERENCES

"Dippers (Cinclidae)." Grzimek's Animal Life Encyclopedia. . Retrieved October 18, 2023 from Encyclopedia.com: https://www.encyclopedia.com/environment/encyclopedias-almanacs-transcripts-and-maps/dippers-cinclidae

"New World Warblers (Parulidae)." Grzimek's Animal Life Encyclopedia. . Retrieved October 19, 2023 from Encyclopedia.com: https://www.encyclopedia.com/environment/encyclopedias-almanacs-transcripts-and-maps/new-world-warblers-parulidae

"Thrushes and Chats: Turdidae." Grzimek's Student Animal Life Resource. . Retrieved October 19, 2023 from Encyclopedia.com: https://www.encyclopedia.com/science/encyclopedias-almanacs-transcripts-and-maps/thrushes-and-chats-turdidae

Asyraf, M., Mohd Abdul Muin, M.A., Shahrul Anuar, M.S. & Rahmad, Z. (2015). Pictorial Guide To The Plant and Bird Life of Byram Mangrove Forest, Penang. Penerbit USM, Malaysia. pp. 190.

Ali, S. 1971. Sunder Lal Hora memorial lecture. Ornithology in India: its past, present and future. Proc. Indian Natl. Sci. Acad., B37: 99-113

Barbaro, L., Rusch, A., Muiruri, E. W., Gravellier, B., Thiery, D., & Castagneyrol, B. (2017). Avian pest control in vineyards is driven by interactions between bird functional diversity and landscape heterogeneity. *Journal of Applied Ecology*, *54*(2), 500–508. https://doi.org/10.1111/1365-2664.12740

Britannica, T. Editors of Encyclopaedia (2011, May 10). tyrant flycatcher. Encyclopedia Britannica. https://www.britannica.com/animal/tyrant-flycatcher

Britannica, T. Editors of Encyclopaedia (2023, September 29). Hirundinidae. Encyclopedia Britannica. https://www.britannica.com/animal/Hirundinidae

Çağan H. Şekercioğlu. (2017). Analysis: The Economic Value of Birds. Retrieved June 12, 2017 from https://www.allaboutbirds.org/news/analysis-the-economic-value-of-birds/

future. Proc. Indian Natl. Sci. Acad., B37: 99-113

Gaglio, D., Cook, T. R., Maëlle Connan, Ryan, P. G., & Sherley, R. B. (2017). *Dietary studies in birds: testing a non-invasive method using digital photography in seabirds*. *8*(2), 214–222. https://doi.org/10.1111/2041-210x.12643

Gallina, a., a. baggio and f. mutinelli, 2005. heavy metal contamination of honey in veneto region (Northheastern Italy): an overview of the situation 2003 – 2004.

In: Proceeding of XXXIX-th apimondia International apicultural congress, 21-26 august 2005, Dublin, Ireland, pp. 145 – 146.

Greenberg, R. (1995). Insectivorous Migratory Birds in Tropical Ecosystems: The Breeding Currency Hypothesis. Journal of Avian Biology, 26(3), 260. https://doi.org/10.2307/3677328

Jetz, W., & Fine, P. V. A. (2012). Global Gradients in Vertebrate Diversity Predicted by Historical Area-Productivity Dynamics and Contemporary Environment. *PLoS Biology*, *10*(3), e1001292. https://doi.org/10.1371/journal.pbio.1001292

Jeyarajasingam, A. (2012). A Field Guide to the Birds of Peninsular Malaysia and Singapore 2nd Edition. Oxford University Press, Oxford. pp. 449.

Karp, D. S. et al. Agriculture erases climate-driven β-diversity in Neotropical bird communities. Glob. Change Biol. 24, 338–349 (2018)

Kéry, M., Gardner, B., & Monadjem, A. (2018). Insectivorous birds consume an estimated 400–500 million metric tons of prey annually. The Science of Nature, 105(5-6), 1-7. https://doi.org/10.1007/s00114-018-1571-z

Kremen, C., Williams, N. M., Bugg, R. L., Fay, J. P., & Thorp, R. W. (2004). The area requirements of an ecosystem service: crop pollination by native bee communities in California. Ecology Letters, 7(11), 1109-1119[2]

Kumar, A., & Mudappa, D. (2010). Insectivorous birds in coffee: The role of birds in the biological control of coffee pests. Journal of Bombay Natural History Society, 107(1), 20-28[3]

Low, Seth H. “Banding with Mist Nets.” Bird-Banding 28, no. 3 (1957): 115–28.

Mansor, M. S. S., Ramli, R., & Sah, S. A. M. (2018). Diet of tropical insectivorous birds in lowland Malaysian rainforest. Journal of Tropical Biology and Conservation, 15(1), 1-12. https://www.researchgate.net/profile/Mohammad-Saiful-Mansor/publication/328537451_Diet_of_tropical_insectivorous_birds_in_Lowland_Malaysian_rainforest/links/5bd824f792851c6b27990dd9/Diet-of-tropical-insectivorous-birds-in-Lowland-Malaysian-rainforest.pdf?origin=journalDetail

Marshall, S. A. (2006). Insects: their natural history and diversity: with a photographic guide to insects of eastern North America. Richmond Hill, Ont.: Firefly Books.

Naves, L. C., and Vooren, C. M. 2006. Diet of black skimmers in southern Brazil. Waterbirds, 29: 335–344.

NRE. (2009). Managing biodiversity in the landscape https://www.nrecc.gov.my/ms-my/pustakamedia/Penerbitan/Guideline%20-%20Managing%20Biodiversity%20in%20the%20Landscape.pdf.

Nur Munira Azman, Latip, A., Mohd, A., Muin, A., Nur Juliani Shafie, & Nurul Liyana Khairuddin. (2011). Avian diversity and feeding guilds in a secondary forest, an oil palm plantation and a paddy field in riparian areas of the kerian river basin, perak, malaysia. *PubMed*, *22(2), 45–64, 2011*.

Nyffeler, M., Şekercioğlu, Ç. H., & Whelan, C. J. (2018). Insectivorous birds consume an estimated 400–500 million tons of prey annually. *The Science of Nature*, 105(7-8). https://doi.org/10.1007/s00114-018-1571-z

O'Connor, R.J. and Shrubb, M. (1986) Farming and birds. Cambridge University Press, Cambridge

Peh, K.S.H., de Jong, J., Sodhi, N.S., Lim, S.L.H. & Yap, C.A.M. (2005). Lowland

Peisley, R. K., Saunders, M. E., & Luck, G. W. (2015). A systematic review of the benefits and costs of bird and insect activity in agroecosystems. Ecological Economics, 122, 20-30[1]

Ryan, P. G., and Jackson, S. 1986. Stomach pumping: is killing seabirds necessary? Auk, 103: 427 –428.

Sekercioglu, Cagan. (2006). Increasing awareness of avian ecological function. Trends in ecology & evolution. 21. 464-71. 10.1016/j.tree.2006.05.007.

Sherry, T. W. (2021). Sensitivity of Tropical Insectivorous Birds to the Anthropocene: A Review of Multiple Mechanisms and Conservation Implications. *Frontiers in Ecology and Evolution*, *9*(May), 1–20. https://doi.org/10.3389/fevo.2021.662873

Sherry, T. W. (2021). Sensitivity of tropical insectivorous birds to the anthropocene: A review of multiple mechanisms and conservation implications. *Frontiers in Ecology and Evolution*, *9*. https://doi.org/10.3389/fevo.2021.662873

Sodhi, N. S., Koh, L. P., Brook, B. W., & Ng, P. K. L. (2004). Southeast Asian biodiversity: an impending disaster. *Trends in Ecology & Evolution*, *19*(12), 654–660. https://doi.org/10.1016/j.tree.2004.09.006

Sridhar, H., Srinivasan, U., Askins, R. A, Canales-Delgadillo, J. C., Chen, C.-C., Ewert, D. N, … Shanker, K. (2012). Positive relationships between association strength and phenotypic similarity characterize the assembly of mixed-species bird flocks worldwide. The American Naturalist, 180, 777–790. https://doi.org/10.1086/668012

Strange, M. & Jeyarajasingam, A. (1993). A Photographic Guide to Birds of Peninsular Malaysia and Singapore. Sun Tree Publishing, Singapore. pp. 270.

Wells DR (1999) The birds of the Thai-Malay Peninsula. London Academic Press, London

Whelan, C. J., Şekercioğlu, Ç. H., & Wenny, D. G. (2015). Why birds matter: from economic ornithology to ecosystem services. *Journal of Ornithology*, *156*(S1), 227–238. https://doi.org/10.1007/s10336-015-1229-y

Whitaker Jr, J. O., Dannelly, H. K., & Prentice, D. A. (2004). Chitinase in insectivorous bats. Journal of Mammalogy, 85(1), 15-18.

Wigglesworth, V. B. (2019). insect | Definition, Facts, & Classification. In *Encyclopædia Britannica*. https://www.britannica.com/animal/insect

Wilson, R. P. 1984. An improved stomach pump for penguins and other seabirds. Journal of Field Ornithology, 55: 109–112.

Yong, D., Qie, L., Sodhi, N., Koh, L., Peh, K., Lee, T., . . . Lim, S. (2011). Do insectivorous bird communities decline on land-bridge forest islands in Peninsular Malaysia? *Journal of Tropical Ecology*, *27*(1), 1-14. doi:10.1017/S0266467410000520

Yong, D., Qie, L., Sodhi, N., Koh, L., Peh, K., Lee, T., . . . Lim, S. (2011). Do insectivorous bird communities decline on land-bridge forest islands in Peninsular Malaysia? *Journal of Tropical Ecology*, *27*(1), 1-14. doi:10.1017/S0266467410000520

Zhang, M., Wang, H., Li, B., & Zhang, Z. (2013). Insectivorous birds reduce insect pests on rice paddies in China. Agriculture, Ecosystems & Environment, 165, 1-10[4]