Institute of Biodiversity and Environmental Conservation

The Influence of Habitat and Arthropods on Insectivorous Birds and Bats in Western Sarawak, Borneo

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The Influence of Habitat and Arthropods on Insectivorous Birds and Bats in Western Sarawak, Borneo

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DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

Natural predation by insectivorous birds and bats has high potential to offer a sustainable solution to pest management in the oil palm plantations. This study aimed to determine the species assemblage, abundance, species richness and activity patterns of insectivorous birds and bats in oil palm plantations (OP) and adjacent forest (SF) in Bau-Lundu region of western Sarawak. The study also assessed the relationship between the abundances of insectivorous predators and arthropods, and influence of various environmental variables (i.e. distance from forest, tree height, temperature, etc.) on their abundances. Bird surveys using point count method observed 318 individuals from 35 species from 18 families, where Rufous-tailed Tailorbird (31.8%) was the most abundant. Acoustic surveys of insectivorous bats recorded 5,299 echolocation calls from 23 species from 6 families, with Verpertilionids being the majority (69.8%) and *Glischropus tylopus* was the most abundant. Sticky traps and pitfall traps collected 8,544 arthropods from 20 orders, while vehicle-mounted tow net captured 42,170 arthropods from 15 orders. The most abundant arthropod order was Diptera (74.8%). Overall, the insectivorous predator and arthropod assemblages have significantly lower abundance and species richness in OP than in SF. The findings of this study do not generally support the hypothesis that higher predator abundance and species richness will result in lower prey abundance. While high bats abundance was reflected by the increase in arthropod abundance in OP, bird-arthropod relationship varied. Insectivorous bird abundance and species richness were negatively affected by distance from forest, but positively influenced by tree height. Insectivorous bats abundance was positively influenced by temperature and wind speed.

Keywords: Biological pest control, insectivorous predators, natural predation, oil palm plantation, secondary forest

Pengaruh Habitat dan Arthropoda terhadap Burung dan Kelawar Insektivor di Sarawak Barat, Borneo

ABSTRAK

Pemangsaan oleh burung dan kelawar insektivor mempunyai potensi tinggi untuk mengawal serangga perosak secara mampan di ladang kelapa sawit. Kajian ini bertujuan untuk menentukan komposisi, kelimpahan, kekayaan spesis serta corak aktiviti pemangsa insektivor di ladang kelapa sawit (OP) dan hutan (SF) di Bau-Lundu, Sarawak. Perhubungan antara kelimpahan pemangsa insektivor dan artropod serta pengaruh persekitaran (cth. jarak dari hutan, ketinggian pokok, suhu, dll.) turut dikaji. Kaedah 'point count' *merekod 318 burung insektivor mewakili 35 spesies daripada 18 keluarga. Perenjak Rimba paling kerap direkod. Tinjauan akustik pula merekod 5,299 panggilan kelawar insektivor mewakili 23 spesies daripada 6 keluarga. Keluarga* Vespertilionidae *(69.8%) menjadi majority, di mana* Glischropus tylopus *paling banyak direkod. Perangkap pelekat serangga dan* 'pitfall' *mengumpul 8,544 artropod daripada 20 order, manakala jaring tunda (*'tow net'*) menangkap 42,170 arthropod daripada 15 order. Order arthropod yang paling banyak ialah Diptera (74.8%). Secara keseluruhan, kelimpahan dan kekayaan spesies pemangsa dan arthropod lebih rendah di OP berbanding SF. Hasil kajian ini tidak menyokong hipotesis bahawa kelimpahan dan kekayaan pemangsa yang tinggi akan mengurangkan kelimpahan arthropod. Walaupun kelawar insektivor menunjukkan respon positif terhadap kelimpahan artropod, burung menunjukkan respon yang berlainan. Jarak dari hutan mempunyai kesan negative terhadap kelimpahan dan kekayaan spesis burung insektivor, manakala ketinggian pokok mempunyai kesan positif. Kelimpahan kelawar insektivor pula dipengaruhi secara positif oleh suhu dan kelajuan angin.*

Kata kunci: *Pemangsa insektivor, kawalan serangga perosak, ladang kelapa sawit*

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LIST OF ABBREVIATIONS

AIC	Akaike's Information Criterion
ANOSIM	Analysis of Similarity
ANOVA	Analysis of Variance
CDC	Commonwealth Development Convention
ED	Forest edge
FELCRA	Federal Land Consolidation and Rehabilitation Authority
FELDA	Federal Land Development Authority
GDP	Gross Domestic Product
GLM	Generalised Linear Model
GPS	Global Positioning System
KESEDAR	Lembaga Kemajuan Kelantan Selatan
Ha	Hectare
IUCN	International Union for Conservation of Nature
LCDA	Land Custody and Development Authority
NGO	Non-governmental Organisations
NMDS	Non-metric Multi-dimensional Scaling
OP	Oil palm plantation
OP200M	200 metres distance into the oil palm plantation
OP400M	400 metres distance into the oil palm plantation
OP600M	600 metres distance into the oil palm plantation
PKEINPK	Perbadanan Kemajuan Ekonomi Islam Negeri Perak
SALCRA	Sarawak Land Consolidation and Rehabilitation Authority
SF	Secondary forest

SLDB	Sarawak Land Development Board
SOPB	Sarawak Oil Palm Board
RISDA	Rubber Industry Smallholders Development Authority
UNIMAS	Universiti Malaysia Sarawak
VIF	Variance Inflation Factor
WAV	Waveform Audio File Format

CHAPTER 1

GENERAL INTRODUCTION

1.1 Study Background

Oil palm (*Elaeis guineensis*) is one of the most rapidly expanding agriculture crops in the tropics, especially in Malaysia, which is one of the world's leading palm oil producers (Awalludin et al., 2015). Despite the economic benefits oil palm have brought to the country, oil palm plantations have significantly degraded the environment by transforming dense forest landscape into simplified vegetation structure, thus reducing local biodiversity (Abdullah & Sulaiman, 2013; Ching et al., 2019; Meijaard et al., 2020). Rising demands for vegetable oil combined with its potential as biofuel, have placed immense pressure on oil-palm producing countries to intensify palm oil production, while minimising negative environmental impacts it poses.

In Malaysia, economic losses from oil palm cultivation is exacerbated by the infestation of Rhinoceros beetle *Oryctes rhinoceros* (Coleoptera: Scarabaeidae), which is known to devastate young oil palms (Kalidas, 2012; Manjeri, 2014), leading to an average of 25% yield loss (Noor Hisham et al., 2013). Other major oil palm pests include red palm weevil *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae), bagworms *Metisa plana* (Lepidoptera: Psychidae) and nettle caterpillars *Setora nitens* (Lepidoptera: Limacodidae) (Murphy & Briscoe, 1999; Darus & Wahid, 2000). Hence, the use of natural enemies to control herbivorous pests would not only minimise the adverse effects of pesticide to the plantation and environment, but also satisfy consumers' demand for environmental-friendly supply (Koh & Wilcove, 2008). The use of natural predation can also lower the cost for pest

control and encourage farmers to retain biodiversity in the agricultural landscape (Wenny et al., 2011; Puan et al., 2012; Puig-Montserrat et al. 2015; Silva et al., 2021).

Birds and bats are important biological control agents due to their high mobility and wide range of dispersal as well as voracious appetite. Their role in suppressing pest populations could reduce reliance on chemical pesticide. Knowledge on the ecological role and factors affecting these natural predators in controlling pests is important in conserving biodiversity in agricultural landscapes (Koh, 2008a). In order to improve the planning and management of oil palm plantations, it is necessary to examine species assemblage, richness and distribution at a landscape-scale. In this study, the roles of insectivorous birds and bats as natural predators to herbivorous arthropods were examined by comparing their impact on arthropod abundance with different levels of landscape structure (e.g. secondary forest, forest edge and oil palm plantation).

1.2 Problem Statement

As one of the worlds' largest oil palm producers, the Malaysian oil palm industry faces a multitude of challenges. Among them are severe pest infestation that adversely affect oil palm yield that result in economic losses (Chung, 2012). For example, infestation by *Tirathaba mundella* in 10% of a hectare of an oil palm estate could cause an average loss of RM97 per hectare (Ming et al., 2021). In order to combat pest infestation, oil palm farmers have relied on chemical control to control the pest population. However, the widespread use of chemical control has affected non-target animals through secondary poisoning (Ravindran et al., 2022). Therefore, there is a need for the incorporation of the use of natural predators as biological pest control agents for a more sustainable management of pests in oil palm plantation.

A growing body of literature has documented the significant impacts of insectivorous birds and bats as natural predators on agricultural pests. Numerous studies comparing arthropod abundance and herbivory rate have shown that insectivorous birds and bats significantly decreased arthropod damage to plants in both agricultural and natural ecosystems. However, predator-prey interactions are not always positive, and they can potentially cause disservice to the ecosystem. Non-selective or generalist insectivorous predators may prey on beneficial arthropods (e.g. mesopredators, parasitoids, pollinators).

Most of these research were conducted in coffee and cacao farms, leaving gaps in knowledge about the ecosystem services provided by birds and bats in other agroecosystems. To date, few studies on the predator-prey interaction have been conducted in oil palm plantation landscape (Wood et al., 1973; Desmier de Chenon & Susanto, 2006; Koh, 2008b). As such, this study could contribute to the understanding of the pest control service provided by the aerial predators in oil palm plantations.

1.3 Research Questions

The main aim of this study was to examine the potential of insectivorous birds and bats to provide ecosystem service as natural predators of oil palm pests by investigating the following questions:

i. What are the species assemblage, abundance and species richness of insectivorous birds and bats and their arthropod preys in the oil palm plantations and adjacent secondary forests?
ii. What are the abundance and species richness of insectivorous birds and bats and their arthropod preys in different ages of oil palm stands (i.e. young and old palm stands)?

iii. What is the relationship between abundance and activity patterns of the insectivorous predators and arthropods?

iv. How does environmental variables (i.e. vegetation and landscape variables, and abiotic factors) influence the abundance, and species richness of insectivorous birds and bats as well as arthropods?

1.4 Hypotheses

This study hypothesises that:

i. The species assemblage, abundance and species richness of insectivorous birds, bats, and their arthropod prey are higher at secondary forest than in oil palm plantation;

ii. The abundance and species richness of insectivorous birds and bats, and their arthropod prey are higher at older oil palm stands than at younger oil palm stands.

iii. Higher insectivorous birds and bats abundance has negative effects on the abundance of arthropods; and

iv. Environmental variables (i.e. vegetation and landscape variables such as distance from forest, age of oil palm stand, tree height, undergrowth density, canopy cover, height of ground vegetation, and abiotic factors like temperature, humidity wind speed, luminosity) may have varying influence on the abundance and species richness of insectivorous birds, bats and arthropods.

1.5 Objectives

Therefore, the objectives of this study are:

i. to determine the species assemblage, abundance and species richness of insectivorous birds, bats, and their arthropod prey along the distance gradient from secondary forest to oil palm plantation and between ages of oil palm stands (i.e. young and old palm stands);

ii. to examine the relationship between (a) the abundance of insectivorous birds and bats with arthropods, and (b) the species richness of insectivorous birds and bats with arthropods;

iii. examine the influence of environmental variables (i.e. vegetation and landscape variables, and abiotic factors) on the abundance and species richness of insectivorous birds, bats and arthropods.

1.6 Outline of Thesis

The first chapter of this thesis will provide background information regarding the problem statements, research questions, hypotheses and objectives of the research. Chapter 2 highlights relevant literatures to provide context for the study and addresses the knowledge gaps. Chapter 3 explains, in general, the methodologies used in this study. Chapter 4 presents the descriptive methodologies and results of the study on the relationship between insectivorous birds and their arthropod prey. Similarly, Chapter 5 presents the methodologies and results of the study on the relationship between insectivorous bats and arthropods. Chapter 6 discusses the research findings and limitations, followed by a conclusion in Chapter 7.

CHAPTER 2

LITERATURE REVIEW

2.1 Oil Palm Cultivation in Malaysia

Oil palm (*Elaies guineensis*) is a tropical palm plant originating from West and Central Africa. Its diverse uses are not limited to food, but also cosmetics, household, industrial products and biofuels (Alam et al., 2015). Oil palm has advantages over other oilseed crops: economically viable with lower production cost, higher yield per area and can be planted in sites unsuitable for most crops (Ching et al., 2019; Meijaard et al., 2020). Oil palm cultivation has thus developed from a small scale crop to one of the most extensively cultivated and profitable sources of revenue for tropical countries (Koh & Wilcove, 2008; Awalludin et al., 2015; Azhar et al., 2015; Muhammad et al., 2019).

Oil palm was first introduced to Malaysia in 1871 by the British and soon, the first commercial estate – Tennamaran estate, was established in Selangor in 1917 (Nambiappan et al., 2018). Oil palm cultivation has since expanded from 55,000 ha in the 1960s to 5.74 million ha of oil palm plantations by 2021 (Figure 2.1; Malaysian Palm Oil Board, 2022), covering almost 18% of Malaysia's total land area. Out of this area, mature oil palm trees accounted for 89.7% of the area while immature oil palm trees made up only 11.3%. The government and private agency estates made up 73.2% of the total oil palm-planted area, whilst 11.7% of the total area were organised smallholders (e.g. FELDA, FELCRA, SALCRA, RISDA, SLDB, KESEDAR, and PKEINPK) and 15.1% were independent smallholders (Malaysian Palm Oil Board, 2022).

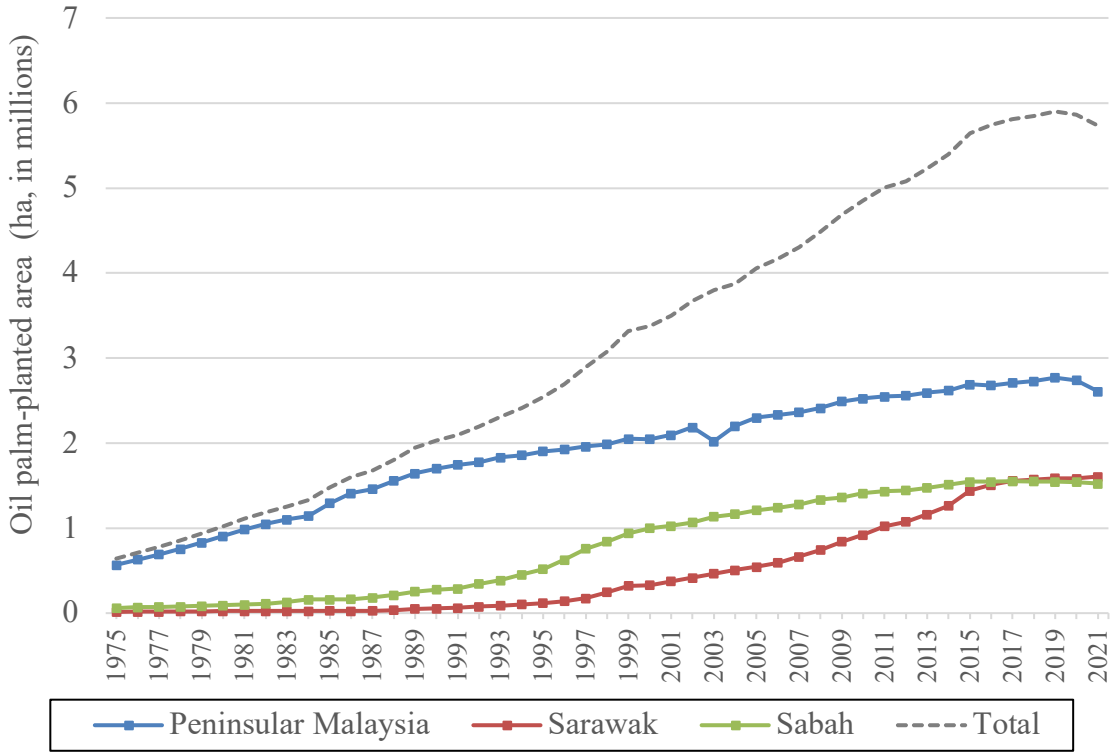

Figure 2.1: Oil palm-planted area in Malaysia from 1975 to 2021. Adapted from data provided by Malaysian Palm Oil Board (2022).

The expansion of oil palm cultivation in Malaysia between 1990 to 2010 was mainly driven by the conversion of disturbed upland forest (38.1%), agroforestry and plantations (34.4%), while only a small part of this conversion took place in pristine forest landscapes (0.1%) and swamp forest (4.0%) (Gunarso et al., 2013). Young oil palm plantations were expanded in cleared forests and areas converted from rubber and older oil palm plantations.

Over the years, Indonesia and Malaysia are the epicentres of the global palm oil production. Malaysia continued to be the second largest producer and exporter of palm oil in 2021, accounting for 18.12 million tonnes of crude palm oil produced and 24.26 million tonnes of global palm oil exports (Malaysian Palm Oil Board, 2022). The production of palm oil is projected to grow by 2.3 million tonnes by 2028 (OECE-FAO, 2019). The Malaysian