NON-RTE/FARMLAND BIRDS AS INDICATOR BIRD SPECIES FOR SUSTAINABLE OIL PALM AGROECOSYSTEM

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

December 2023

FPAS 2023 17

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Oil palm certification schemes, such as the Roundtable on Sustainable Palm Oil (RSPO), currently overlook important biodiversity indicators like farmland birds commonly found in plantations. While the focus of certification bodies is primarily on rare, threatened, and endangered species, yet farmland birds, which are commonly not listed species, are one of the crucial components of healthy agroecosystems. This study provides crucial baseline data for establishing an indicator species concept in avian biodiversity within oil palm landscapes. While past studies focused on insects in measuring habitat characteristics, this pioneering research introduces a workflow for identifying and developing indicator farmland bird species for oil palm plantations sustainability assessment. The methodology consisted of three main steps where i) sets of candidates of oil palm bird indicator species for four sub-regions in Southeast Asia; Peninsular Malaysia, Borneo, the Philippines, and Sumatera were developed based on information gathered from previously published studies, ii) Similarity Percentages Analysis (SIMPER) was performed on the bird species list to identify indicator bird species by analysing the contribution of each species to the observed similarity between samples in each region, and iii) point count and opportunistic bird surveys were conducted in selected locations in Peninsular Malaysia to validate indicator bird candidates obtained from literature search. By combining information from previous studies and field verification surveys, the study identified the most suitable bird species as indicators for oil palm agroecosystems. Overall, conservation priority species were found to be less common in oil palm plantations. All indicator lists of the sub-regions comprise of Least Concern (LC) bird species with 97% except for Peninsular Malaysia where Javan Myna was recorded as Vulnerable (VU) with 3%. Hence the majority of ecosystem services in oil palm are provided by common farmland birds species with a total of 19 species out of 20, which should be included as indicator species as part of oil palm certification standards. Validation from field analysis recorded Javan Myna and Long-tailed Parakeet as VU with 3% while the rest are LC bird species. When comparing field data with the indicator species list, Rembau recorded the highest similarity with 90%, followed by Bangi (70%), Keratong (65%), Banting (50%) and Serdang (45%). Meanwhile, opportunistic surveys from Bangi and Serdang recorded similarity of 50% and 45% respectively based on indicator species list. This study also found that indicator bird species are associated with geographical locations and endemism where all regions were found to have different species occurrence. For example, Borneo did not record Zebra Dove and Yellow-vented Bulbul, Sumatra did not record Pied Fantail whereas the Philippines did not record Spotted Dove. Therefore, regional avian biodiversity information in the development of indicator species lists to support oil palm environmental sustainability is recommended. Insectivores were recorded the most prevalent in both published literature data and field surveys whereas nectarivores were less frequently found in oil palm plantations. By implementing the concept of common bird indicators in oil palm certification schemes, the findings can effectively promote biodiversity conservation and enhance ecosystem services in agricultural landscapes.

Keywords: Agroecosystem, Biodiversity, Farmland birds, Oil palm sustainability

SDG: GOAL 15: Life on Land

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

BURUNG-BURUNG BUKAN NADIR, KEPUPUSAN, TERANCAM/LADANG SEBAGAI SPESIES PENUNJUK UNTUK KELESTARIAN AGROEKOSISTEM KELAPA SAWIT

Oleh

NURSYAMIN HANIS BINTI ZULKIFLI

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Skema pengiktirafan kelapa sawit seperti Meja Bulat mengenai Minyak Sawit Lestari (RSPO) tidak mempertimbangkan indikator biodiversiti sepenuhnya, seperti burung ladang yang mana mereka sering dijumpai di dalam ladang-ladang. Sementara itu fokus utama oleh badan-badan pengiktirafan adalah terhadap spesies unik dan terancam, tetapi burung-burung ladang yang tidak tersenarai adalah salah satu komponen penting dalam agroekosistem yang sihat. Kajian ini menyediakan data asas yang penting untuk mewujudkan konsep spesies penunjuk dalam biodiversiti burung dalam landskap kelapa sawit. Sementara kajian-kajian lepas memberi tumpuan kepada serangga dalam mengukur ciri-ciri habitat, penyelidikan perintis ini memperkenalkan aliran untuk mengenal pasti dan membangunkan penunjuk spesies burung tanah ladang untuk penilaian kelestarian ladang kelapa sawit. Metodologi kajian ini merangkumi tiga langkah utama di mana i) calon-calon spesies burung penunjuk di dalam kelapa sawit untuk empat kawasan di Asia Tenggara; Semenanjung Malaysia, Borneo, Filipina, dan Sumatra dibina berdasarkan maklumat yang telah dikumpulkan daripada kajian sebelum ini, ii) data senarai spesies burung dianalisis menggunakan Analisis Peratusan Persamaan (SIMPER) untuk melihat persamaan antara sampel-sampel pada setiap kawasan, dan iii) kaedah *point count* dan tinjauan burung oportunis dijalankan di beberapa tempat terpilih di Semenanjung Malaysia untuk mengesahkan spesies burung penunjuk yang telah diperoleh daripada carian kesusasteraan. Berdasarkan maklumat yang dikumpul melalui kajian-kajian terbitan sebelum ini dan tinjauan pengesahan lapangan, calon-calon spesies burung penunjuk yang terbaik untuk agroekosistem kelapa sawit telah dikenal pasti. Secara keseluruhan, spesies utama bagi pemuliharaan kurang dijumpai di dalam ladang-ladang kelapa sawit. Semua senarai penunjuk di empat kawasan merangkumi spesies burung berstatus Sedikit Bimbang (LC) dengan 97% kecuali di Semenanjung Malaysia dimana Tiong Jambul Jawa berstatus Lemah Ancaman (VU) telah direkod sebanyak 3%. Oleh itu, sebahagian besar servis ekosistem di dalam kelapa sawit diperuntukkan daripada spesies burung ladang biasa dengan jumlah 19 spesies daripada 20 spesies, dimana spesies-spesies tersebut sepatutnya termasuk sebagai spesies penunjuk didalam standard pensijilan kelapa sawit. Pengesahan daripada analisis lapangan merekodkan Tiong Jambul Jawa dan Bayan Nuri berstatus VU sebanyak 3% manakala selebihnya adalah spesies burung berstatus LC. Apabila membandingkan data lapangan dengan senarai spesies penunjuk, Rembau merekodkan persamaan tertinggi iaitu 90%, diikuti Bangi (70%), Keratong (65%), Banting (50%) dan Serdang (45%). Manakala tinjauan oportunis mendapati Bangi dan Serdang masing-masing merekodkan persamaan sebanyak 50% dan 45% berdasarkan senarai spesies penunjuk. Kajian ini juga mendapati spesies burung penunjuk bersekutu dengan lokasi geografi dan endemisme dimana semua kawasan didapati mempunyai kejadian spesies yang berbeza. Sebagai contoh, Borneo tidak merekodkan Tekukur dan Merbah Kapur, Sumatra tidak merekodkan Sambar Murai Gila manakala Filipina tidak merekodkan Merbuk. Oleh itu, maklumat biodiversiti burung serantau dalam menghasilkan senarai spesies penunjuk untuk menyokong kelestarian alam sekitar kelapa sawit adalah digalakkan. Burung-burung insektivor direkodkan paling tinggi didalam data kajian-kajian terbitan dan tinjauan lapangan manakala burung-burung nektar dijumpai terendah di dalam ladang-ladang kelapa sawit. Penerapan konsep spesies burung penunjuk biasa didalam rancangan pensijilan kelapa sawit akan memberi manfaat yang berkesan kepada pemuliharaan biodiversiti dan mempertingatkan servis ekosistem di dalam landskap agrikultur.

Kata kunci: Agroekosistem, Biodiversiti, Burung-burung ladang, Kelestarian kelapa sawit

SDG: Matlamat 15: Kehidupan darat

ACKNOWLEDGEMENTS

All praise to Allah the Almighty, the Lord of the Universe. I am profoundly thankful to my supervisor, Assoc. Prof. Dr. Badrul Azhar Md. Sharif for his valuable guidance, unwavering support, and expert advice throughout the research process in shaping the direction and quality of this work. My sincere thanks to co-supervisors, Dr. Norhisham Ahmad Razi and Dr. Nurul Wahida Othman, for their valuable insights and constructive feedback.

To my sisters, Nor Hidayah, Nurhanisah and Nurhafizah, whose love, encouragement, and understanding have been my constant pillars of strength, I am deeply grateful. Thank you for always celebrating even my smallest achievements.

To Nonsans team, thank you for the academic support and emotional encouragement since my day one here. To Muhammad Syafiq Yahya and Sharifah Nur Atikah, I am truly grateful for all your guidance and assistance. To my dearest girls, Dinah Hanani, Hazeeqah Hashim and Maziah Omar, thank you for the wonderful friendship, through my ups and downs, 17 years and counting. To coffee, you deserve a shoutout too. Your warmth and caffeine-fueled energy were essential partners in creating this piece.

And to my parents, this thesis is lovingly dedicated to you.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Date: 11 July 2024

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LIST OF ABBREVIATIONS

BBS	Breeding Bird Survey
CBC	Common Bird Census
CBD	Convention on Biological Diversity
CPO	Crude palm oil
CSPO	Certified Sustainable Palm Oil
EFB	Empty fruit bunch
EU	European Union
FBI	Farmland Bird Indicator
FFB	Fresh fruit bunch
GAP	Good Agricultural Practices
HCS	High Carbon Stock
HCV	High Conservation Values
IPM	Integrated Pest Management
ISO	International Organization for Standardisation
ISPO	Indonesian Sustainable Palm Oil
IUCN	International Union for Conservation of Nature
LC	Least Concern
LUCA	Land Use Change Analysis
MPOB	Malaysian Palm Oil Board
MPOCC	Malaysian Palm Oil Certification Council
MSPO	Malaysian Sustainable Palm Oil
MyGAP	Malaysian GAP
NT	Near Threatened

PKO	Palm kernel oil
RSPO	Roundtable on Sustainable Palm Oil
RTE	Rare, threatened and endangered
SEIA	Social and Environmental Impact Assessment
SIMPER	Similarity Percentages Analysis
SPOTT	Sustainable Palm Oil Transparency Toolkit
UK	United Kingdom
VU	Vulnerable
YAP	Years after planting

CHAPTER 1

INTRODUCTION

1.1 General background

Several studies have consistently shown that the majority of birds in oil palm landscapes were represented by common and least concerned species (Azhar et al., 2011; Cagod and Nuñeza, 2012; Amir, Noor and Hambali, 2015; Bernardo, 2017; Mulyani et al., 2018; Mohd-Azlan et al., 2019). There is less number of conservation priority species that have been recorded in oil palm plantation. The principles and criteria of Roundtable on Sustainable Palm Oil (RSPO) have yet to emphasize on associated biodiversity as a certification requirement. Associated biodiversity is represented by natural colonization in agroecosystem influenced by the surrounding environment (Tscharntke et al., 2012). Associated biodiversity includes all organisms (agriculturally beneficial, neutral and harmful organisms) that are present in cultivated fields such as pest control of insects in Asian paddy rice by frogs and apple seed pollination by wild bees (Vandermeer, 2014; Morelli and Tryjanowski, 2017; Martínez-Sastre et al., 2020). Whereas agroecosystem refers to natural habitat and ecological systems altered by humans for food, fibre or other agricultural outputs. While resembling the systems they replace, their intricate nature is mainly from the interaction between ecological processes and socio-economic (Conway, 1987). Associated biodiversity including birds, bats, and insects at the edge or within oil palm plantations can serve as natural predators (Azhar et al., 2015; Nurdiansyah et al., 2016). In addition, common species within associated biodiversity, can be utilized as an indicator for oil palm environmental sustainability. To date, none of the oil palm sustainability certifications has incorporated the indicator species concept into their standards on biodiversity conservation.

The Roundtable on Sustainable Palm Oil (RSPO) was established with the aim of promoting environmentally sound oil palm management. A comprehensive set of standards has been developed for the stakeholders to comply with in order to receive Certified Sustainable Palm Oil (CSPO) (RSPO, 2020). However, there is a lack of focus given for associated biodiversity (i.e farmland birds) as listed in Principle 7.12.6 and 7.12.7 (Principles and Criteria for the Production of Sustainable Palm Oil, 2018). Rare, threatened or endangered (RTE) species were highlighted in the certification process principles instead. Similar to RSPO principles, the Malaysian Sustainable Palm Oil (MSPO) under Principle 5 and Indonesian Sustainable Palm Oil (ISPO) under Principle 3.7 focused on the same aspect of RTE management in oil palm plantations (Kuntom, Kushairi and Choo, 2015; Purwanto, 2019; Comparative Table of ISPO 2020 and RSPO 2018, 2021). The emphasis on protecting RTE species made by the three organizations led to the decline in common farmland species where it will deteriorate ecosystem services in oil palm plantations. Merely focusing on RTE species to determine biodiversity loss is not always a quality indicator when common species are ignored (Gregory et al., 2005).

Ricotta et al. (2021) defined indicator species as species that frequently occur in the area. Farmland birds as indicator species in agriculture must also be based on the region per se considering different regional dynamics (Whittingham et al., 2007; Wretenberg et al., 2007; Jerrentrup et al., 2017). The selection of birds as a biodiversity indicator is due to variety of benefits. First, birds' ecology is the most studied compared to other taxa hence the immense knowledge about this group (Kirk et al., 2020). Second, many of the species provide rapid respond towards environmental changes. The impacts of agricultural practices such as pesticide application can also be measured using bird indicators as a tool to monitor and alleviate the harmful effects on the environment (Kirk et al., 2020). Birds and insects are mainly affected due to pesticide application, which was reported to be the second vital contributor to the decrease in population in agricultural plantations (Jambari et al., 2012; Sánchez-Bayo and Wyckhuys, 2019). Third, birds are more likely to be detected and utilize habitat complexity compared to other species (Amir, Noor and Hambali, 2015). Fourth, birds can be easily monitored through audio and visual observation than other taxa. Finally, birds contribute to many ecosystem services, such as natural predators to pests (Denmead et al., 2017), as well as economic benefit to agricultural lands (Kirk et al., 1996). Such example is shown by bird's crucial role as seed disperser; a frugivore would consume different fruits and eventually lead to high plant species richness (Whelan, Sekercioglu and Wenny, 2015). Spiderhunters were found to pollinate durian while sunbirds were among the frequent visitor of wild banana (Yumoto, 2000; Ssali and Sheil, 2019). In addition, cuckoo has been used as indicator species for bird hotspots in European countries as the cuckoo-call depends on change of climate and seasons (Tryjanowski and Morelli 2015; Morelli et al., 2017).

Farmland bird trends have been used widely to indicate the health of agroecosystems. Previous studies have emphasized the importance of accurately representing species groups in order to minimize bias when setting bird indicators (Gregory et al., 2005). One notable example is the Farmland Bird Indicator (FBI) program initiated by the UK Government in 1970 to monitor farmland bird trends (The Royal Society for the Protection of Birds, 2021). This program combines data from the Common Bird Census (CBC) and Breeding Bird Survey (BBS) conducted by volunteer birdwatchers. Over the course of four decades, the surveys have recorded the presence of 19 common species in UK farmlands and documented the declines in farmland bird populations. Likewise, the European FBI had tracked 33 common farmland species in 18 European Countries and farmland bird trend had been predicted to decrease between 2002 and 2025 over land-use changes in those areas (Scholefield et al., 2011). The Dutch FBI recorded about 30% drop in farmland birds from 2000 until 2016 with 21 species decline out of 27 indicator species (Statistics Netherlands, 2021). The findings indicate effects of intensive agricultural methods on farmland bird species shown by trends obtained from the survey for indicator bird species.

Conservation efforts aimed at enhancing biodiversity levels, particularly focusing on birds, have been implemented worldwide in agricultural landscapes. These efforts include reducing pesticide application and promoting effective pest control by adopting beneficial crop management practices (Faria and Morales, 2020). The simplified habitat of oil palms has greatly reduced bird species, however it can still protect some of the bird species mostly with improved heterogeneous landscape management and maintaining forest patches within and surrounding oil palm plantations (Azhar et al., 2011; Yudea and Santosa, 2019). Hence, birds may serve as indicator species of a healthy oil palm agroecosystems.

This study is the first to demonstrate the selection of indicator bird species for healthy oil palm agroecosystem based on published studies coupled with primary data gathered from the field. This indicator bird species concept is aimed to be promoted in oil palm certification schemes. In this study, indicator bird species will be identified from published papers in the four sub-regions in Southeast Asia: Peninsular Malaysia, Borneo, the Philippines and Sumatra. Bird species composition will be identified and used as a set of indicator species in oil palm plantations for each region. The baseline avian biodiversity information from this study will shed new insight in the development of indicator species concept for oil palm environmental sustainability.

1.2 Problem statement

Wildlife-friendly farming or land sharing strategy should be seriously considered by oil palm industry stakeholders. Common bird species with little conservation value comprise the majority of birds in oil palm agroecosystems, however the principles and criteria of oil palm certificates (i.e., RSPO) tend to mainly focus on RTE and forest species (i.e., orang utan, tiger and Great Hornbill). These RTE and forest species are uncommon in most oil palm production landscape. The certification schemes also have yet to implement indicator species concept into assessing oil palm biodiversity. More attention should be given to associated farmland biodiversity in oil palm plantations compared to visiting forest species due to effects from replanting and the use of pesticides. While FBI uses the indicator concept to monitor farmland bird trends by combining data from CBC and BBS, this study extends the concept for oil palm sustainability. In addition, farmland birds as indicator species in agriculture must be based on the region itself due to geographical and regional dynamics.

1.3 Aim and objectives

The aim of this research is to promote the indicator bird species concept into oil palm certification schemes. The objectives of this research were:

1. To demonstrate the selection of indicator bird species for a healthy oil palm agroecosystem.

2. To identify indicator bird species and bird feeding guild for certified sustainable oil palm plantations in different regions.
3. To measure the sustainability of selected Peninsular Malaysia oil palm plantations.

1.4 Hypothesis

H_o: Common farmland birds serve as effective indicator species in measuring oil palm sustainability

H_1: Common farmland birds do not serve as effective indicator species in measuring oil palm sustainability

1.5 Significance of study

Through this research, the oil palm certification schemes will understand common farmland birds are as important as the RTE species. The organizations will also be able to implement the indicator bird concept into setting a standard for oil palm stakeholders to comply with as well as improving oil palm industry in terms of its environmental sustainability. The study will contribute to the development of a comprehensive set of indicator species specific to each region, enabling oil palm certification schemes to effectively assess and monitor the biodiversity of oil palm plantations. Additionally, a comprehensive list of bird species found in selected oil palm plantations in Peninsular Malaysia will be generated, providing valuable insights into the avian diversity within these landscapes.

CHAPTER 2

LITERATURE REVIEW

2.1 Oil palm cultivation and expansion

Oil palm, scientifically known as *Elaeis guineensis* jacq., is a widely recognized and predominant source of vegetable oil worldwide. With a lifespan of over 25 years and a remarkable yield, oil palm has become a crucial crop in the vegetable oil industry (Woittiez et al., 2017). It was first introduced in 1817 to Southeast Asia to be consumed as food until the 1980s however it is now succeeding in vegetable oil palm industry (Aziz, Chamhuri and Batt, 2021; Qaim et al., 2020). While the United States, China and Brazil are among the top producers of vegetable oils from maize and soy beans, only Malaysia, Indonesia and Nigeria cultivate oil palms 10% from their land areas (Meijaard and Sheil, 2019). Oil palm is recognized as an efficient crop, requiring only 0.26 hectares of land to produce one ton of oil (Umar et al., 2021). The two main oils produced by oil palm trees are crude palm oil (CPO) and palm kernel oil (PKO) where the oils are extracted from orange-yellow mesocarp and white kernel respectively (Woittiez et al., 2017). In Malaysia, CPO alone has produced 18.12 million tonnes while fresh fruit bunch (FFB) approximately 15 tonnes/hectare in 2021 making the country as one of the world's highest exporters to the top seven markets; India (23.1%), China (12.0%), the European Union (EU) (10.5%), Turkey (4.5%), Kenya (4.3%), Pakistan (3.9%) and lastly the Philippines (3.7%) (Malaysian Palm Oil Board, 2022c). Apart from its widespread use as a cooking oil, the edible palm oil that is extracted from the mesocarp contains beneficial components such as vitamin E, carotenoids and phytosterols as an antioxidant (Giri and Bhatia, 2020; Rashid et al., 2021; Sundram, Sambanthamurthi and Tan, 2003). Both CPO and PKO are also widely used in non-food sectors such as chemical products, pharmaceutical and cosmetic products (Khatiwada et al., 2021).

The life cycle of oil palms encompasses four distinct yield phases; immature (2-3 years after planting, YAP), young mature (4-7 YAP), mature (8-14 YAP), and yield decline (15-25 YAP) (Rhebergen et al., 2018). Oil palm has become one of the most fast-growing agriculture crops and has grown bigger over the last 100 years from a small-scale agroforestry due to high demand of vegetable oil (Woittiez et al., 2017). Since 2000, the cultivation of oil palms in the East Malaysia has expanded from coastal to the inland area (Li et al., 2020). Furthermore, the oil palms' year-round production makes them as a stable source of income compared to other cash crops (Meijaard and Sheil, 2019). However, Miettinen, Shi and Liew (2011) and Stibig et al. (2014) suggested that besides logging, expansion of oil palm plantation is also one of the major causes of deforestation in Malaysia. As of 2020, approximately 724,000 hectares of land are being utilized for oil palm cultivation just in Malaysian smallholders (Malaysian Palm Oil Board, 2022a). As total cultivated areas latest in year 2020, Peninsular Malaysia recorded 2.74 million hectares (46.7%) converted to oil palm plantations, followed by Sarawak and Sabah with 1.59 million hectares (27.0%) and 1.54 million hectares (26.3%) respectively (Malaysian Palm Oil Board, 2022b). Indonesia recorded 12.3 million hectares of oil palm plantations and followed by the Philippines with 65,000 hectares (International Production Assessment Division, 2022). Oil palms were originally cultivated on suitable mineral soils however the cultivation has shifted to peatlands in replacing the lessening mineral soils (Omar et al., 2010). Oil palm depends highly on the temperature and is better cultivated at lower altitude ranging 0-100 m in which yield is reduced in cooler regions or at high elevation with low temperature thus making Malaysia as one of the important palm oil producers due to its high temperature (Li et al., 2020). The expansion of oil palm plantations has led to simplified landscapes, resulting in a loss of biodiversity, including natural predators such as predatory beetles and farmland birds (Chung et al., 2000; Donald, Green and Heath, 2001; Newbold et al., 2015). Meanwhile, Koh and Wilcove (2008) recorded the decrease in butterfly species richness by 78% in Malaysian and Indonesian oil palm.

Due to its large usage of terrestrial area, contribution to biodiversity by oil palm plantations is not as important as forest (Tscharntke et al., 2005). Peat swamp forest converted to oil palm plantations had led to an increased temperature and soil acidification, besides decreased in humidity (Anamulai et al., 2019). On the other hand, conversion of tropical peatlands for oil palm cultivation has been linked to greenhouse gas emissions with carbon loss of approximately 60 mg of CO^2 per hectare per year in the first 25 years of land clearing (Murdiyarso, Hergoualc'h and Verchot, 2010). Meanwhile, forest conversions have negatively impacted air and water purification, regeneration of soil and nutrient cycles (Qaim et al., 2020). However, palm waste is making its way as one of the biofuels in Malaysia, securing country's power resource. The crude oil yield calculated at about 48% annually is potential at contributing energy sustainably (Umar et al., 2021). Over the last 100 years, oil palm plantation has grown larger from the increased trade in China and India, while the EU as the largest consumer of palm oil thus resulted in large-scale production of palm oil in Southeast Asia (Azhar et al., 2015; Qaim et al., 2020).

2.1.1 Smallholders vs. industrial oil palm plantations

Smallholders are referred to landowners with accumulated oil palm land less than 40.46 ha who manage their own farmland (Kannan et al., 2021). More than 50% of the farmers deal with the mills through middlemen (Schoneveld et al., 2019). The industry has improved the livelihood of rural farmers more than the rubber and subsistence farmers (Balde et al., 2019). The oil palm smallholders also have lowered the hunger levels and less money loan for food purchases when compared to other type of farmers (Balde et al., 2019). However, smallholders are more vulnerable to price drops in palm oil, as agriculture is their primary source of income (Nabara et al., 2021). As example, most smallholders in Riau province preferred Dura palms as their planting materials because of its heavy large kernels so they are able to earn more since farmers are being paid per kilo despite the fruit quality (Jelsma et al., 2019). The smallholders also, especially non-certified, mostly harvest irregularly depending on the price of FFB or when cash is needed (De Vos et al., 2021). The group is divided into two different categories which are schemed and independent smallholders where schemed smallholders cultivated oil palm through systematic organizations with the help from the government while the latter did not (Rizal et al., 2021). In Kalimantan Indonesia, these smallholders are then further classified into six categories (Table 2.1.1) (Schoneveld et al., 2019).

Table 2.1.1 : Demographic characteristics of Kalimantan smallholders

Group	Demography
Subsistence farmers	1. The average size of total oil area is four hectares. 2. Live in or local to their own farms. 3. Either indigenous (e.g., Malay or Dayak ethnic) or second-generation Javanese migrants. 4. Often depend on oil palms as their earnings. 5. Mostly planted rubber before cultivating oil palm. 6. The majority planted oil palm without prior knowledge or experience. 7. Obtained plots though inheritance.
Early adopters	1. Almost similar to subsistence farmers (e.g., origin and ethnicity). 2. The average size of total area is five hectares. 3. Amongst the early oil palm cultivators. 4. Planted rubber before cultivating oil palm. 5. The majority have prior knowledge and experience on oil palm as they work with corporate plantations. 6. Obtained plots through inheritance.
Migrant laborers	1. The majority are first-generation of Javanese migrants. 2. The average size of total area is four hectares. 3. The majority have prior knowledge and experience on oil palm as they work with corporate plantations. 4. Planted other subsistence crops before cultivating oil palm. 5. Obtained plots from the government transmigration initiatives or purchased plots.
Migrant farmers	1. Almost similar to migrant laborers (e.g., origin and total area). 2. The majority of them tried to obtain more land to plant another crop. 3. The late adopters of oil palm cultivation.

Table 2.1.1 : Continued

	4. Planted rubber and other subsistence crops before cultivating oil palm. 5. Live near to their farms. 6. Obtained plots from the government transmigration initiatives or purchased plots.
Entrepreneur	1. The average size of the total area is seven hectares. 2. Diverse ethnicity but dominated by Javanese origin farmers. 3. Fewer have prior knowledge and experience of oil palm. 4. Engaged in many types of farming before cultivating oil palms. 5. Mostly are still involved with small business activities (e.g., shop-keeping, oil palm trade and construction). 6. The majority live nearby to their plantations.
Local elites	1. The average size of total area is 15 hectares. 2. The wealthiest among other groups and have political power. 3. High diversity in ethnicity. 4. The most educated group completed tertiary education as compared other groups. 5. The majority are white-collar employees and main income are from civil service. 6. Minority live nearby to their plantations.

(Schoneveld et al., 2019)

Approximately 39% and 9% of the independent and managed smallholders, respectively, often grow other crops (e.g., bananas, chillies, maize) together with the oil palm trees in the same area (Nelly et al., 2022; RSPO, 2022b; Saadun et al., 2018). While only about 6% of the smallholders practice agroforestry, 16% of them contributed to the Malaysian palm oil production (Ratnasingam et al., 2021). Smallholders in Riau province on the other hand, practice monoculture as their standard management with lower percentage of pineapple, and rubber and cocoa intercropping on peatlands and mineral soils respectively (Jelsma et al., 2019). As of July 2022, roughly 159,859 smallholders with total area 459,124 hectares have been RSPO certified (RSPO, 2022b). Although the business is managed in a small scale, Malaysian and Indonesian smallholders contribute about 40% towards the oil plantation industry (RSPO, 2022b). On the other hand, 40% of the smallholders in Indonesia do not follow the oil palm standards hence the less yield quality as compared to Malaysian smallholders (Aziz, Chamhuri and Batt, 2021). In management context, smallholders were found to have greater soil moisture, canopy cover and provide more suitable habitat for forest species besides they are managing a better drainage system as compared to plantations (Oon et al., 2019; Yahya et al., 2020).

2.1.2 Oil palm pest management

Oil palm plantations, like other agricultural systems, are susceptible to pest infestations. Leaf-eating insect such as nettle caterpillar (*Limacodidae* spp.) and bagworm (*Psychidae* spp.) are the major pests of oil palm in Malaysia and Indonesia damaging its leaves and inhibiting tree growth while globally, lady beetles (Coleoptera: Coccinellidae) and green lacewings (Neuroptera: Chrysopidae) are the common pest species in agriculture (Wood, 1968). Yield is reduced up to 50% due to bagworms defoliation while nettle caterpillars has caused about 30% loss (Kamarudin and Wahid, 2010; Potineni and Saravanan, 2013). Although some infestations might be on a small-scale, it is however affecting the leaf area index causing unhealthy oil palm (Wood, 1978). At high infestation of pests, farmers could have loss about RM 288 per hectare per year (Darus and Wahid, n.d.). A study done by Wood and Liau (1978) found that rats, another important pest of oil palm, could damage the crop and reduce the yield at about 240 kg oil per hectare per year. Rats also consume developing fruitlets and damage the immature oil palms that can kill the plant at some point (Wood and Chung, 2003; Woittiez et al., 2017).

Chemical and biological control are the two primary approaches used to contain pest problems where chemical control uses pesticide or insecticide meanwhile the latter exercises environmentally sound management by using natural predators (Wood, 2002). Chemical control methods typically involve the application of pesticides by farmers once pests are detected in the plantations, aiming to prevent larger-scale infestation. However, studies have shown that the use of chemicals can have negative consequences on animal populations, particularly after land conversion and fertilizer usage (Brühl and Zaller, 2019). Pesticides, considered the second most significant factor contributing to biodiversity loss in agricultural plantations after land clearing, has a negative impact on numerous forest species, including birds, insects, and large mammals. (Jambari et al., 2012; Qaim et al., 2020; Sánchez-Bayo and Wyckhuys, 2019). Not only they altered animal population, but pesticides are also linked to environment pollution due to chemicals residue, interrupt pests' natural enemies which could mess up the food chain and pests could also develop resistance towards chemicals (Darus and Wahid, n.d.). Ecological services will be disrupted when chemical inputs are applied excessively causing the imbalance of natural predators against pests (Igbinosa, 1992; Wood, 2002). The practice of blanket-spraying of herbicides as to control weed and other ground vegetation in oil palm plantations may become non-selective by eliminating potential beneficial plants towards the farm productions and reduce undergrowth coverage (Nobilly et al., 2021; Tohiran et al., 2019). For example, grasses may reduce water and nutrient losses, and promote soil health to improve oil palm output (Tohiran et al., 2019). Even more concerning, farmers who are frequently exposed to pesticides have been found to develop leukemia, asthma, dermatitis and even Parkinson disease

(Bassil, Vakil and Sanborn, 2007; Norkaew et al., 2015; Praneetvatakul et al., 2013).

To comply with RSPO, the introduction of natural enemies has been implemented as an alternative to chemical control methods. Biological predators such as ants, birds and bats provide biological control services (Evans et al., 2011, Denmead et al., 2017) by predating on pests and indirectly increasing the yield (Maas et al., 2015, Maine and Boyles 2015). According to Maas et al. (2015), birds and bats prey on arthropods thus lower the herbivory pest and leaf damage on young oil palms. The presence of insectivorous bird species such as Oriental Magpie-robin *Copsychus saularis*, Common Tailorbird *Orthotomus sutorius*, Germain's Swiftlet *Aerodramus germani* and Common Iora *Aegithina tiphia* in all agricultural habitats demonstrates the potential role of the insectivore as insect pest predators (Yahya et al., 2022). Nurdiansyah et al. (2016) reported bush cricket, *Nisitrus vittatus* (Orthoptera: Gryllidae) as a common predator of artificial caterpillars and mealworms in Indonesia.

Introducing rotational cattle grazing techniques in oil palm plantations can be an effective strategy to replace herbicide applications for controlling ground vegetation. This approach not only reduces costs but also enhances understory vegetation diversity, benefiting oil palm production (Nobilly et al., 2021). Unlike conventional herbicide use, rotational cattle grazing maintains optimal undergrowth height while preserving beneficial plants that support oil palm production (Tohiran et al., 2019). Coffee farmers in Indonesia integrate livestock mulch (i.e. goats and cows) to improve land quality naturally from agricultural waste (Kuswadi and Fitriani, 2021). This mechanism can also be applied in oil palm production landscapes to extend the function of rotational cattle grazing technique.

Besides natural predators, the oil palm itself contains good potential soil microbes that can be used to improve ecosystem services in plantation (Kamarudin, Seman and Masri, 2019). Each species of microbes has its own specialty, for example *Bacillus thuringiensis* (Bt) that can be converted into bioinsecticides (Ali et al., 2010). Approximately 90% of bagworms populations (*Metisa plana*) in smallholders were reduced when pheromone traps were applied together with Bt aerial spraying (Ahmad et al., 2017). A biological rodenticide, *Sarcocytis singaporensis* derived from host-restricted apicomplexan protozoon was found to reduce rat population better than the rat poisons such as warfarin and brodifacoum with at least 58% mortality rate (Jakel et al., 1999; Naim et al., 2011).

2.1.3 Oil palm habitat management

2.1.3.1 Planned biodiversity

Increasing habitat complexity is crucial in promoting animal diversity of oil palm. Monoculture practices, which result in a single canopy layer and lack of understory vegetation and woody debris, contribute to a decrease in biodiversity (Qaim et al., 2020). Introducing flowering and fruiting plants around or within oil palm brings in understory birds that can serve as natural predators besides bats and butterflies (Azhar et al., 2015; Nurdiansyah et al., 2016). Similarly in Indonesian oil palm, the increased in frugivorous and nectarivorous birds abundance were recorded due to uncultivated patches between the oil palms (Warren-Thomas et al., 2022). Maintaining non-cropped patches near to the farms is crucial for species to escape from agricultural activity especially for small area farms (Salek et al., 2018). Polyculture management is also proven in increasing bird species richness in oil palm plantations including nocturnals (Atikah et al., 2019; Yahya et al., 2017). Kamarudin et al. (1996) suggested that planting beneficial plants such as wild poinsettia, *Euphorbia heterophylla* L. brings in natural enemies of lepidoptera for example bagworms. Higher number of foraging birds was also due to complexity in vegetation cover in oil palm plantations (Azhar et al., 2013; Warren-Thomas et al., 2022). Non-oil palm vegetations such as hedgerows and grassland strips outside oil palm plantations are important to boost forest patches and benefit biodiversity in agriculture (Salek et al., 2018).

In addition, creating non-oil palm vegetation at plantation edge boosts unique plant species such as *Ficus* spp. since plantation edge receives more light exposure and less disturbance from harvesters hence increases frugivorous bird species (Jambari et al., 2012; Luke et al., 2019). An increased in bird phylogenetic and evolutionary diversity was found in rubber plantations due to increased height of herbaceous plants and higher densities of fruit tree stems in which the same management is highly possible to be applied in other agricultural systems (Jayathilake et al., 2021). Besides birds in oil palm plantations, nectarivorous bats were also proven to be highly dependent on flowering plants in rubber plantations (Tanalgo, Sritongchuay and Hughes, 2021). As a result, a higher amount of dead plant debris led to a greater diversity of macrofungal in polyculture smallholdings as compared to monoculture smallholdings and plantations (Shuhada et al., 2020). Reduced stream debris was also said to have negatively affected fish body mass and benthic microhabitats in Peninsular Malaysian oil palm plantations (Chua et al., 2020). Higher abundance of birds in smallholding, especially the arboreal omnivores and terrestrial frugivores were positively affected by the short distance of oil palm to the next forest patch to which monoculture estates can emulate the habitat management (Azhar et al., 2013; Warren-Thomas et al., 2022). Rhinoceros Hornbill *Buceros rhinoceros*, Asian Paradise Flycatcher *Terpsiphone paradisi* and Dusky Eagle Owl *Bubo coromandus* are amongst the forest-dependent species which were found roosting in monoculture smallholdings before they flew to nearby forest patch or logged peat swamp forest (Jambari et al., 2012; Atikah et al., 2019).

Similarly, in Indonesia, the conservation of forest fragments has been shown to be of utmost importance. Forests have significantly higher species richness, with 35 species recorded compared to only three in smallholdings (Warren-Thomas et al., 2022). Higher bird phylogenetic diversity was also found in rubber plantations neighbouring to forests suggesting the positive impact of forest fragments towards bird diversity and abundance in agriculture (Jayathilake et al., 2021). In order to conserve nearby forest patches, re-wetting the oil palms surrounding can lower the risk of fires from farms to the forests to protect forest species. However, water tables delivered zero effects on avian diversity and vegetation complexity on the farm itself (Warren-Thomas et al., 2022).

Polyculture smallholdings were found to have a better microclimate as compared to monoculture plantations. Increased air temperature, wind speed and soil acidity in plantations proved that polyculture systems significantly affected the oil palm soil and microclimates (Anamulai et al., 2019). Almost all agricultural management systems have the same effect towards bird composition. Strawberry farms in California that lack of semi-natural habitat within and surrounding the farms were found to be less visited by birds hence the decrease in pest natural predator (Olimpi et al., 2022). Likewise, poor avian phylogenetic diversity recorded in monoculture rubber plantations as compared to mixed vegetation and fruit orchards (Jayathilake et al., 2021).

In Indonesia, it has been observed that the replanting of oil palm has led to alterations in arthropod composition, specifically reducing the abundance of Coleoptera and spiders, as well as species richness (Pashkevich et al., 2021). Thus, polyculture management has a huge potential in lowering the effects of oil palm replanting. Practicing plant diversification systems also benefits the environment itself. Oil palm plantations in Indonesia intercropped with pepper increased the atmospheric water recycling whereas oil palm intercropped with cocoa reduced carbon footprint (Khasanah et al., 2020). Coherently in Malaysian oil palms, grass cover ($1m^2$) increased when intercropped with black pepper (51.2%), bactris (43.9%) and cacao (43.4%) as compared to monoculture oil palms (Ashraf et al., 2018). Conversion to oil palms from peat swap forests has negatively influenced relative humidity however, intercropping oil palms with black pepper and cacao could maintain its optimal relative humidity (Anamulai et al., 2019; Ashraf et al., 2018). From an economic perspective, intercropping oil palm with cocoa also lowers the establishment cost and hence increases labour returns (Khasanah et al., 2020).

2.1.3.2 Canopy cover

Studies have shown that low canopy cover in oil palm plantations can increase the presence of foraging birds (Azhar et al., 2013, Yahya et al., 2017). Conforming to these studies, the complex interactions in rubber plantations also recorded positive number of species with low canopy cover paired with higher densities of fruit plants (Jayathilake et al., 2021). Oil palm plantations, regardless of its management system, were found to receive higher light intensity as compared to peat swamp forests due to the shorter oil palm trees (Anamulai et al., 2019). When the ground is exposed to better sunlight and promotes ground vegetation, the condition will provide a suitable foraging site for the birds (Sheldon, Styring and Hosner, 2010).

2.1.3.3 Undergrowth cover

Weedy vegetation contributes to increased predation rates in oil palm plantations hence, reduced use of herbicides plays an important role in sustainable management (Kamarudin and Wahid, 2010) besides enhancing soil functions (Darras et al., 2019). Introducing weeds and epiphytes are a good way to invite insectivorous birds (i.e Yellow-bellied Prinia *Privinia flaviventris)* as these plants provide nesting sites while also increasing arthropods abundance for birds foraging resources (Desmier de Chenon and Susanto, 2006; Jambari et al., 2012). Good undergrowth management could be implemented with rotational cattle grazing in oil palm plantations as a replacement for herbicide usage (Nobilly et al., 2021; Tohiran et al., 2019). Contributive undergrowth coverage could be saved to enhance soil nutrients in oil palm plantations by grazing undergrowth plants that the cattle only favor (Tohiran et al., 2019). Seeds produced by ground vegetation improve number of granivorous birds (i.e Zebra Dove *Geopelia striata*) (Azhar et al., 2013) in oil palm plantations as a potential seed disperser. Undergrowth plants are also needed by Red Junglefowl *Gallus gallus* as a hideaway from predators hence uncovered harvesting paths are best to avoid (Jambari et al., 2012). Similarly, higher numbers in grass cover resulted in increased bird species richness and abundance (Yahya et al., 2017). Lack of ground vegetation in monoculture oil palm was found to affect predator and decomposer abundance as a result from herbicide application in plantations (Ashraf et al., 2018).

Replanting of oil palm has negatively affected the abundance of soil macrofauna thus a good management in ground cover could potentially improve the land structure (Pashkevich et al., 2021). Nabara et al. (2021) reported approximately 27% of the smallholders in Peninsular Malaysia planted legume crops to improve soil and water, in turn, it reduces ground pressure. Indonesian coffee farmers have been actively planting creeping legumes to preserve soil fertility and protect from direct precipitation, especially for critical lands rehabilitation (Kuswadi and Fitriani, 2021). On the other hand, weeds, Chinese Violet *Asystasia gangetica* play less role in ecological services as they can compete with oil palms for nutrients (Koh, 2008b). Managing a good ground cover also intensifies water retention in soils that can reduce competitive weeds in oil palm plantations while focusing in boosting natural predators (Woittiez et al., 2017).

2.1.4 Associated biodiversity

Associated biodiversity is the part of biodiversity that naturally colonizes an agroecosystem because of the surrounding environment (Tscharntke et al., 2012). Increased in species richness is associated with the increase of natural habitat percentage around the agricultural landscape while species richness in tropical sites is highly associated with landscape homogeneity (Outhwaite et al., 2022). Previous finding revealed spiders and butterfly species abundance, and butterflies and birds species richness correlate with the non-cropped elements with lower agrochemicals application compared to cropped elements proving the importance of non-cropped elements as habitat to diverse fauna community (Salek et al., 2018). While birds depend heavily on semi-natural habitat, plants and arthropods also are positively affected with presence of non-cropped habitat and absence of fertilizer input in the area in which proving the importance of habitat heterogeneity in farmland diversity (Billeter et al., 2008; Jambari et al., 2012). Natural enemies that provide pest control services are also highly dependent on the surrounding landscape. The highest percentage of natural enemies is associated with high edge density, high semi-natural habitat proportions and a low percentage of arable land (Martin et al., 2019). While landscape characteristics contribute to crucial biodiversity association, spatial scales between tropical and non-tropical landscapes also play roles in species richness and abundance (Outhwaite et al., 2022).

2.1.5 Land-sharing vs. land-sparing

A massive demand in agricultural production, mainly due to increasing food demand, has called for sustainable management in reconciling biodiversity with agriculture. Two main strategies were frequently practiced by farmers and stakeholders which are land-sharing and land-sparing strategies. Land-sharing, in which some authors mentioned as wildlife-friendly farming, focuses on conserving biodiversity within the agricultural land which resulting in less agricultural production and smaller area of land being set aside for conservation (Fischer et al., 2008; Green et al., 2005). It means that biodiversity and agricultural production co-occur in the same land where the strategy includes reserving some forest patches across the agricultural lands and maintaining a small range of heterogeneity within and around the production landscapes such as diversified crops and hedgerows (Benton et al., 2003; Fischer et al., 2006; Fischer et al., 2008; Harvey et al., 2006). Land-sharing strategy however is associated with low-yield intensified system and hence, produce larger footprints to achieve same yield level as land-sparing strategy if there is increased in agricultural demands (Fischer at el., 2014; Green et al., 2005; Kremen, 2015; Phalan et al., 2011). In oil palm production landscape context, smallholders and polyculture farming systems practice land-sharing strategy where habitat complexity has positively influenced understory birds, bats and butterflies as well as presence of uncultivated patches and grassland strips outside oil palm plantations (Atikah et al., 2019; Azhar et al., 2015; Qaim et al., 2020; Salek et al., 2018; Warren-Thomas et al., 2022). Thus, wildlife-friendly farming is best practiced for species that have high adaptability of spatial continuity and climate change which suits well with oil palm production landscape based on the higher abundance of common bird species recorded (Amir, Noor and Hambali, 2015; Azhar et al., 2011; Green et al. 2005; Peh et al., 2006; Matson and Vitousek, 2006).

In contrast, land-sparing strategy refers to one land restricted mainly for biodiversity conservation purposes while the other land is utilized to produce high-yield intensified agricultural production (Green et al., 2005). Compared to land-sharing system, this alternative strategy is mostly practiced by large industrial companies to fulfill and maximize agricultural demand rather than biodiversity conservation peculiarly when demands for food, fibre and fuel are increasing (Grass, Batary and Tscharntke, 2021; Green et al., 2005). Thus, in order to produce high yield, the stakeholders utilized high number of pesticides and fertilizers, and very low crop diversity presence in the production landscapes whereas the set aside nature reserves are usually spared on government-managed land due to less incentive for stakeholders to handle conservation lands (Fischer et al., 2008). A huge difference can be seen between these two lands where land-sparing agricultural landscapes practice homogeneity with very low habitat complexity while the spared biodiversity lands are completely the opposite, separated from any human disturbances (Fischer et al., 2008; Haila, 2002). While the set-aside biodiversity land benefits forest species, it might in turn lead to species loss due to intensification (Fischer et al., 2008).

Both approaches should be seriously incorporated with a proper policy framework, regardless the aim of the output. While land-sparing could possibly cause illegal agricultural land expansion, land-sharing too will disrupt ecosystem services from the agricultural intensification if environmental policies are not strengthened (Kremen, 2015). Moreover, policy makers and government agencies should take into account the suitability of these main aspects prior to strategy decision which are i) topography where complex topography suits land-sharing more, ii) landscape productivity where naturally poor soil nutrient might reduce agriculture yield in land-sparing, iii) socioeconomic preferences in which farmers do not necessarily favour optimal yield due to high cost in chemicals usage thus lower yield is still profitable, and iv) consumer demand curves that has been greatly shifted towards environmental-friendly products (Dorrough, Moll and Crosthwaite, 2007; Fischer et al., 2008; Hole et al., 2005).

2.2 Bird diversity in oil palm plantations

The expansion of oil palm cultivation and the resulting deforestation have led to a significant decrease in bird species richness and diversity. The removal of trees during land clearance for oil palm cultivation has created canopy gaps, disrupted the nesting habitats of certain bird species and affected overall bird diversity and richness (Lemelin et al., 2007; Simamora et al., 2021). Moreover, lack of suitable habitats for foraging is also upsetting bird diversity in oil palm plantations and eventually leads to a higher number of open habitats and generalist species (Peh et al., 2006; Warren-Thomas et al., 2022). Bird species in Indonesian oil palm smallholders recorded lower body mass as large-bodied seed dispersers (Bucerotidae and Trogonidae) were absent. The farms were also found to match only 21% with the forest species while most insectivores (Aegithinidae, Campephagidae, Chloropseidae, Dicruridae and Timaliidae) were not observed (Warren-Thomas et al., 2022). Amazonian oil palm also recorded poor diversity of older avian lineages as compared to forest fragments (Cardoso et al., 2021). The application of insecticides has also reduced bird occurrence in plantations and predation on leaf-eating caterpillars (Howe, Lovei and Nachman, 2009). Approximately 50% of bird species in peat swamp forest was affected from forest conversion to peatland oil palm plantations in Peninsular Malaysia and Indonesia (Azhar et al., 2011; Warren-Thomas et al., 2022). Similarly, Simamora et al. (2021) recorded only 6% out of 214 birds species in West Kalimantan oil palms. Habitat specialist birds like Black Baza *Aviceda leuphotes* and Racket-tailed Drongo *Dicrurus* sp. are greatly affected by land clearings thus the lower number in oil palm plantations in Banting-Jenjarom especially with forest patches being absent (Amir, Noor and Hambali, 2015). However, farmland birds are considered not affected by land clearing.

Farmlands birds constitute a functional group that are specifically adapted to farmland environments or typically located in agricultural areas (Siriwardena et al., 2008; Kirk et al., 2020). A higher abundance of tailorbird, bulbul, robin and myna in oil palm plantations in Teluk Panglima Garang-Pulau Carey and Banting-Jenjarom indicate open country birds utilize open areas like oil palm plantations (Amir, Noor and Hambali, 2015). Open habitat nocturnal birds such as Barn Owl *Tyto alba*, Large-tailed Nightjar *Caprimulgus macrurus* and Sunda Scops-owl *Otus lempiji* were also recorded and they have positively responded to oil palm density (Atikah et al., 2019). The African ant-following bird was also observed to be highly anticipated in opened areas than in high forest cover (Kupsch et al., 2019). Migratory wetland species such as Purple Heron *Ardea purpurea*, Chinese Pond Heron *Ardeola bacchus* and Lesser Whistling-duck *Dendrocygna javanica* were found to forage and breed in oil palm plantation in Peninsular Malaysia due to presence of flood-controlled drains or ponds (Azhar et al., 2013; Jambari et al., 2012). Non-oil palm vegetation planted around farmhouses such as bananas in smallholdings also increases understory birds (Azhar et al., 2015). While increased tree diversity leads to a better complexity in oil palm plantations, variety in oil palm stand age also gives positive impact on number of foraging birds (Azhar et al., 2013; Zemp et al., 2019). The low bird abundance in oil palm plantations as compared to various fruit trees agroforestry orchards proved the importance of tree diversity towards oil palm bird communities (Yahya et al., 2022). On top of that, bird phylogenetic diversity in connected riparian reserves was found to have matched with the large forest fragments (Cardoso et al., 2021). Thus, bird diversity as well as aquatic insect biodiversity in oil palm plantations could be improved with riparian reserves which can benefit species movement between habitat through landscape connectivity besides the positive effect towards agricultural production (Cardoso et al., 2021; Ishak et al., 2021).

2.3 Oil palm certification standards

To ensure sustainable farming from the stakeholders and smallholders, a certification schemes were introduced. According to the International Organization for Standardisation (ISO), certification is a written assurance of a product, service or system that achieves the requirements. The issuance of a certificate is based on an auditing process carried out by acknowledged independent certification bodies (Ainie, Kushairi and Choo et al., 2015). Malaysia, Indonesia and Thailand are among those with sustainability certifications which are MSPO, ISPO and Thai GAP respectively (Aziz, Chamhuri and Batt, 2021). RSPO, an independent international organization, was established in 2004 to deliver standards for environmentally sound oil palm management globally before the countries developed their own certification schemes. A set of standards have been decided for the stakeholders to comply with in order to receive CSPO (RSPO, 2022a). Through certifications and training, smallholders are required to opt for organic fertilizers, better quality seeds and lower pesticides usage (Kunz et al., 2019). Certified farmers also benefit from subsidized, yet organic fertilizer (De Vos et al., 2021). As of 2022, 5673 million ha, 683 000 ha and 586 000 ha have been MSPO certified for total planted areas, organized smallholders and independent smallholders respectively (MPOCC, 2022). Generally, certification is introduced to provide transparency in oil palm chain, besides bringing Malaysian palm oil to a better level globally (Kumaran, 2019).

On the contrary, the majority of the smallholders are RSPO registered but only they were arranged mostly by the receiving system (Kunz et al., 2019). Many smallholders lack the necessary knowledge and appropriate equipment to meet the requirements, such as reducing greenhouse gas emissions as outlined in Principle 7.10 (Kunz et al., 2019). In Malaysia, an independent organization, the Malaysian Palm Oil Certification Council (MPOCC) is working closely together with the Malaysian Palm Oil Board (MPOB) to deliver environmentally sound management by the smallholders. The bodies are also supplying the knowledge to the smallholders in terms of improving and maximizing their yield through the latest technologies, at once combating poverty and providing a better future for rural development (Aziz, Chamhuri and Batt, 2021). Through sustainable certification, there is an increase in CPO yield besides international acknowledgements (Aziz, Chamhuri and Batt, 2021).

2.3.1 Biodiversity principles and sustainable managements in certification

Through principles and criteria, standards are set for smallholders and stakeholders to comply with in order to receive certification for their plantations. Overall, RSPO consists of eight principles, while MSPO and ISPO have set four and seven standards respectively (Sustainable Palm Oil Transparency Toolkit, n.d.). However, this chapter only focuses on sustainable management and biodiversity conservation adjacent to the topic (Table 2.3.1).

Table 2.3.1 : The RSPO, MSPO and ISPO criteria in sustainable management and biodiversity conservation

Criteria	Indicators		
	RSPO	**MSPO**	**ISPO**
Land conversion and conservation of primary forests	7.7.1 • No new planting on peatland, regardless of depth after 15 November 2018, in existing plantation areas or new development areas 7.12.1 • Land clearing since November 2005 has not damaged primary forest or any	4.7.1 • Oil palm shall not be planted on land with high biodiversity value unless it is carried out in compliance with the National and/or State Biodiversity Legislation. • No conversion of Environmentally Sensitive Areas to oil palm as required under Peninsular Malaysia's National Physical Plan and the Sabah Forest Management Unit under the Sabah Forest Management License Agreement. For Sabah and Sarawak, new planting or	1.1.1 • Plantation business actors shall have Location Permit provided by the Regency/Provincial Spatial Plan (RTRK/RTRWP) 1.1.2 • Plantation land that originates from converted production forest area shall be obligated to have Permit for Release of Forest Area from the Ministry of Environment and Forestry or Indonesian Investment Coordinating Board. • Plantation opened from production forest areas and limited production forests must obtained Principle Permit for Area Swapping. • Procedures for changes in forest area designation and function, the process of issuing a permit to release the area and a letter of approval in principle for area swap, shall refer to the following regulations: ○ Government Regulation No. 10 of 2010 in conjunction with PP No. 60 of 2012 replaced by No.104 of 2015 concerning Procedures for Exchanging the Designation and Function of Forest

Table 2.3.1 : Continued

	area to protect or enhance High Conservation Values (HCV). • Land clearing since 15 November 2018 has not damaged HCVs or High Carbon Stock (HCS) forests. A historic Land Use Change Analysis (LUCA) is conducted prior to any new land clearing, following RSPO LUCA guidance	replanting of an area 500ha or more requires an Environmental Impact Assessment. For areas below 500ha but above 100ha, a Proposal for Mitigation Measures (PMM) is required. 4.7.2 • New planting and replanting may be developed and implemented on peat land as per MPOB guidelines on peat land development or industry best practice. 4.7.3 • A comprehensive and participatory social and environmental impact assessment shall be conducted prior to establishing	Areas ○ Regulation of Minister of Forestry No.P.33 Year2010 jo P.17 Year 2011 jo P.51/MENLHK/SETJEN/KUM.1/6/2016 replaced by Regulation of Minister of Environment and Forestry No. P.96/MENLHK/SETJEN/KUM.1/11/2018 jo P.50/MENLHK/SETJEN/KUM.1/9/2019 concerning Procedures for the Release of Convertible Production Forest Areas ○ Regulation Minister of Forestry No. P.32 of 2010 jo No. 41 of 2012 jo P.27/Menhut-II/2014 replaced by No. P.97/MENLHK/SETJEN/KUM.1/11/2018 concerning Forest Area Swapping • In the 1990s, a Joint Decree of the Minister of Forestry, Minister of Agriculture and Head of BPN No. 364/Kpts-II/90, No. 519/Kpts/HK.050/7/90 and No. 23-VIII-1990 was issued which addressed the provisions for releasing forest areas and granting the Right to Cultivate for agricultural business development. Forest areas that can be released into agricultural business land are forest areas based on the ability of the land to be suitable for agricultural business and according to forest use, are not maintained as permanent forest

Table 2.3.1 : Continued

	document. 7.12.2 • HCVs, HCS forests and other conservation areas are identified.	new plantings or operations. • Social and Environmental Impact Assessment (SEIA) shall include previous land use or history and involve independent consultation as per national and state regulations, via participatory methodology which includes external stakeholders. • The results of the SEIA shall be incorporated into an appropriate management plan and operational procedures developed, implemented, monitored and reviewed. • Where the	areas. 3.7 • Identified as HCV and protected areas. 3.9.1 • A document that shows development of a new plantation does not open natural forests and peatland is made available, in accordance with the applicable statutory regulation.

Table 2.3.1 : Continued

		development includes smallholder schemes of above 500ha in total or small estates, the impacts and implications of how each scheme or small estate is to be managed should be documented and a plan to manage the impacts developed, implemented, monitored and reviewed.	
Biodiversity conservation	7.12.6 • All RTE species are protected regardless they are identified in an HCV assessment or not. • Educating the	4.5.1 • An environmental policy and management plan which shall be in line with the relevant country and state environmental laws shall be established, effectively communicated and implemented.	3.7 • Determine the results, establish standard operating procedure on the maintenance and develop site map and management plan of identification on HCV and protected areas. • Circulation on HCV and protected areas to the

Table 2.3.1 : Continued

	workforce of the status of RTE species and taking disciplinary measures towards the workforce if found to capture, harm, collect, trade, possess or kill RTE species in accordance with company rules and national law. 7.12.7 • The status of HCVs, HCS forests after 15 November 2018,	• The environmental management plan shall cover the following: ○ Environmental policy and objectives. ○ The aspects and impacts analysis of all operations. • An environmental improvement plan to mitigate the negative impacts and to promote the positive ones, shall be developed, implemented and monitored. • A programme to promote the positive impacts should be included in the continual improvement plan. • An awareness and training programme shall be established	

Table 2.3.1 : Continued

	peatland, other conservation areas and RTE species is monitored. The results from monitoring are reported to management plan.	and implemented to ensure that all employees understand the policy, objectives and management plans and are working towards achieving the objectives. • Management shall organize regular meetings with workers where concerns of workers about the environmental quality are discussed.	

(Comparative Table of ISPO 2020 and RSPO 2018, 2021; MSPO, 2022; Sarawak Oil Palm Plantation Owners Association, n.d.)

2.3.2 Good agricultural practices (GAP)

GAP scheme is introduced to manage agricultural farms sustainably while intensifying the yield with environment, food quality and workers welfare are taken care of as well (Department of Agriculture, 2016). Malaysian GAP (myGAP), previously known as Good Practice Scheme of Malaysia was established in 2002 in accordance with Malaysian Standard MS 1784:2005 Crop Commodities – Good Agriculture Practices. To run a GAP certified plantation effectively and maximizing yield, technical measures such as road and waterways infrastructure, especially on peatlands and hilly mineral soils, and development of fire prevention must also be seriously considered (Jelsma et al., 2019). GAP concepts were also introduced by MPOC at the Rio Earth Summit to set an example in agriculture development (Table 2.3.2) (Basiron, 2008). Through RSPO certification, certified smallholders were able to acquire better quality planting materials in which better yield is produced as compared to non-certified smallholders (De Vos et al., 2021). The non-certified smallholders mostly use discarded seeds from plantations, buy from informal distributors that often sell Dura seeds or use pulled saplings.

Table 2.3.2 : GAP concepts by MPOC

Criteria	Indicator
Water management	• High-water table at low-lying areas are drained without exposing damaged soil horizons. • Silt pits are constructed to conserve soil moisture in other areas. • Palm oil mill effluent (POME) is used to irrigate plants. • Water is away from roads by diverting to the field.
Pruned fronds	• Pruned fronds are arranged as inter-rows.
EFB	• EFB acts as mulch for water conservation and source of organic fertilizer by placing around young or between mature plants.
Reduce soil compaction	• Light vehicles (e.g., mini-tractors, wheelbarrows) with low-pressured tires are used to collect fruits. • Natural grasses are maintained to improve soil quality.
Ecosystem maintenance	• Natural swamp areas. • Riparian reserves along streams. • Natural water courses (e.g., streams and rivers)
Soil fertility maintenance	• Leguminous cover crops are introduced in early oil palm establishment to fix nitrogen in root nodules.

Table 2.3.2 : Continued

	• Application of fertilizers on good weather to avoid rain washout and polluting the waterways.

(Basiron, 2008)

Good GAP example can be seen in plantations in Riau Indonesia where the farmers usually stacked prune dead leaves in a row or u-shape for easy access between the rows, increasing ground cover and enhance nutrient recycling (Jelsma et al., 2019). Certified smallholders also gained more knowledge in applying a balanced nutrient in fertilizer (e.g., nitrogen, phosphorus and potassium) whereas the non-certified smallholders applied more than 50% for nitrogen only (De Vos et al., 2021). Overall, from choosing Tenera seedlings, regular 14 days harvesting frequency to having FFB transported within 24 hours after harvesting have positively affected oil palm yield (De Vos et al., 2021). However, effective GAP schemes depend highly on labour availability and local supply chains for FFB's pricing and collection frequency (De Vos et al., 2021).

2.3.3 Loopholes in certification systems

The principles set by RSPO, MSPO and ISPO tend to exclude common associated biodiversity such as farmland birds and other taxa. The certification process emphasized the RTE species instead. While common farmland species already make a huge contribution towards agriculture as biological control agent and pollinators, ignoring the species may also cause imbalance in ecosystem services (Baker et al., 2018; Gaston et al., 2018; Gregory et al., 2005; Maas et al., 2015; Ssali and Sheil, 2019; Whelan, Sekercioglu and Wenny, 2015; Woittiez et al., 2017; Yumoto, 2000). Ecosystem structure and services could be at stake with the decrease of common species abundance although at a small scale (Gregory and van Strien, 2010). Moreover, there has been a lack of awareness provided by certification bodies to the certified stakeholders and smallholders in implementing land-sharing strategy. While the certification criteria have restricted plantings on HCVs and HCS forests areas to spare for biodiversity conservation, it somehow failed to implement wildlife-friendly farming concept in which it will cause species intensification for high turnover species and eventually lead to massive reduction of species (Fischer et al., 2008).

Lack of interactions between certification bodies with the smallholders are also one of the crucial contributions towards the low total land certified. A study in smallholders in Riau province found they are yet to be supplied knowledge on GAP and significance of a balanced nutrition on oil palm productivity (Jelsma et al., 2019). Due to lack of awareness, empty fruit bunch (EFB) application is still not common for the farmers and peatland smallholders significantly prefer chemical weeding. Plantings on peatlands are also yet to be given proper trainings in maximizing use of fertilizers efficiently as they are still unclear with the specific nutrient requirements needed.

2.4 Indicator species in ecology

Indicator species is used as a substitute for a parameter that is difficult to measure and capture directly due to technical or practical constraints (Hilty and Merenlender, 2000; Landres, Verner and Thomas, 1988; Lindenmayer, Margules and Botkin, 2000). However, implementing indicator species has to be practical and they need to comply with certain criteria, and they should not also be seen as a short cut in environment monitoring (Table 2.4) (Gregory and van Strien, 2010). Besides that, choosing only one species over a group of species in an area is less effective as indicator species in a bigger territory because different species may respond differently to environmental changes despite they are of the same group (Gregory and van Strien, 2010; Lindenmayer, 1999).

Table 2.4 : Characteristics of workable indicator species

Attribute	Details
Representative	Covers a group of species of the taxa
Immediate	Able to give regular updates
Simplifying	Provides complex information in a simplified way
Easily understood	Straightforward information to audiences
Quantitative	Precise and accurate measurement
Responsive to change	Gives swift response to ecological changes
Susceptible to analysis	Information can be dismantled to analyze the trends
Realistic to collect	Able to obtain data within financial and manpower resources for a long period of time
Indicative	Species selected reflects ecosystem health
Policy relevant	Provides information for policy makers to establish laws
Stability	Resistance from ecological alteration
Compliancy	Indicator system is easy compliance to human amendment

(Gregory and van Strien, 2010)

Birds, as well as bats, have been extensively used as indicator species in agricultural lands because they are easily monitored especially through acoustics observations (Doohan et al., 2019). A study done to determine the best fit indicator species in ecology found that birds as the most cost-effective taxa due to easy identification in the fields and less labor is required, followed by butterflies and plants (Winarni et al., 2020). Mammal, on the other hand, requires the highest cost as equipments and labor are needed for mammal identification and followed by herpetofauna (Winarni et al., 2020). However, a study suggested that the initial indicator of a quality habitat are frogs and toads as they have semi-permeable skin that are highly sensitive to environmental changes in both aquatic and terrestrial in which it can be extended to measure oil palm farms and the surrounding water bodies (Amarasinghe et al., 2021). Study done in Czech Republic found bees and wasps were highly occurred in open canopy areas especially with the presence of spruce (Horak et al., 2019). Equivalently, presence of dragonfly juveniles as well as the adults indicate the availability of clean water and a healthy wetland (Ng, 2020). The reduced in their richness in agricultural sites and disturbed forests show the impact of poor freshwater ecosystem towards dragonflies which has called for revision in the effectiveness of different riparian widths in oil palm plantations (Luke et al., 2017). The increased richness of Odonata species indicates high water temperature and vegetation cover meanwhile lower species richness is due to high water level and total dissolved solids (Ishak et al., 2021; Kietzka, Pryke and Samways, 2016). Eutrophication of waterways due to chemical runoff in oil palm smallholders and plantations can also be monitored where dissolved oxygen positively affected Odonata species whereas effect of water pH shows the opposite (Ishak et al., 2021; Kietzka, Pryke and Samways, 2016).

Similar research can evaluate data from published studies to identify the indicator bird species in other regions now planted with oil palm such as South American countries (e.g., Columbia, Brazil, Costa Rica). This indicator species concept can be expanded to other taxa such as bats and butterflies. For instance, butterflies were found to react to woods condition indicating butterflies as biological marker and they also acted as species richness indicator in the area (Sharma et al., 2020). The presence of shade cover and dead logs were found to highly affect bat diversity in coffee farms suggesting bats as another indicator species of agroecosystem after birds and butterflies (Huang et al., 2019). More than that, cattle grazing behaviour and consistent visits in certain areas could indicate weed and undergrowth plants coverage in oil palm plantation (Tohiran et al., 2019). Indicator species concept can also be extended to measure forests quality. In herpetofauna, presence of narrow-mouthed frogs, fork-tongued frogs and tree frogs reflect the density of moist forest as moist forests provide habitable conditions for the species whereas savanna forests recorded highest abundance of families Gekkonidae and Scincidae, especially Rough-scaled sun skink *Eutropis rugifera* (Amarasinghe et al., 2021). Moreover, narrow-mouthed frogs (Microhylidae) were recorded only in Balinese moist forests in which the species can act as indicator species for moist environment (Amarasinghe et al., 2021). The study also had determined Crested Toad *Ingerophrynus biporcatus* and Palmated chorus frog *Microhyla palmipes* as indicator species for moist habitats, while Balinese snake-eyed skink *Cryptoblepharus balinensis* for deciduous forests, Jatna's bent-toed gecko *Cyrtodactylus jatnai*, Rough-scaled sun skink and Common house gecko *Hemidactylus frenatus* for savanna forests and lastly Sumatran puddle frog *Occidozyga sumatrana*, Four-lined tree frog *Polypedates leucomystax* and Crab-eating frog *Fejervarya cancrivora* for both moist and deciduous habitats (Amarasinghe et al., 2021). Besides fauna as bio-indicator, flowering plants can be used to evaluate the canopy cover of the area as they mirror the amount of sunlight received (Ng, 2020). Nonetheless, a reliable indicator results could be improved and is indeed crucial if contributions of each species in specific temporal and spatial scale is well understood (Gregory and van Strien, 2010; Lindenmayer, 1999).

2.5 Bird as indicator species

Birds are one of the indicators of ecosystem healthiness as they are easy to detect and utilize habitat complexity more than other groups (Amir, Noor and Hambali, 2015). They are abundant, a well-established phylogenetic status, occur in marine and terrestrial habitats, give swift response in regard to environmental changes, easy to detect, and lastly surveying birds are inexpensive (Gregory and van Strien, 2010). In the past decades, coalminers of the Canary Island depended on Atlantic Canary *Serinus canaria* to signaled them of poisonous fumes where the death of the birds saved the miners' lives (Gregory and van Strien, 2010).

The high occurrence of Bold-striped tit-babbler *Mixornis bornensis* in disturbed and opened areas in West Kalimantan shows its potential as general indicator species of agriculture lands while smallholder oil palms hold two potential indicator species which are Pink-necked green pigeon *Treron vernans* and Cinnamon bittern *Ixobrychus cinnamomeus* (Simamora et al., 2021). Large scale oil palm plantations in Malaysia recorded seven bird species that make the bird community in that area which are Javan Myna *Acridotheres javanicus,* Oriental Magpie-robin, Common Tailorbird, Yellow-vented Bulbul *Pycnonotus goiavier*, White-throated Kingfisher *Halcyon smyrnensis*, Germain's Swiftlet and Black-naped Oriole *Oriolus chinensis* (Yahya et al., 2022). These studies also corroborated with Jaroenkietkajorn, Gheewala and Scherer (2021) in which birds and insects measure species diversity in Thailand. Meanwhile in another continent, a significant decrease in frugivorous African birds indicates the impacts of deforestation towards flora and fauna whereas insectivores are highly potential as anthropogenic pressure indicator (Kupsch et al., 2019; Ng, 2020). On the other hand, the Golden oriole *Oriolus oriolus* reflects the presence of oak stands in the particular area in Czech Republic (Horak et al., 2019). The presence of White-rumped Shama *Copsychus malabaricus*, Black-bellied Malkoha *Rhopodytes diardi,* Black Magpie *Platysmurus leucopterus* and Black-and-yellow Broadbill *Eurylaimus ochromalus* where they are forest associated species, in agroforestry orchards indicates fruit trees in the area (Yahya et al., 2022). Asian Openbill Stork *Anastomus oscitans* and Black-headed Ibis *Threskiornis melanocephalus* are the two indicator species of South Indian that migrate to paddy fields during monsoons (Menon, 2021). These species are strongly dependent on food availability, influenced by landscape and soil characteristics, and react rapidly to ecological changes, hence the easy monitoring of environment quality of paddy fields (Menon, 2021; Siddig et al., 2016). Black-headed Ibis is also listed as Near Threatened (NT), measuring the success of threatened species restoration efforts where rare birds' trends can also illustrate changes in nature and through agri-environmental management (Gregory and van Strien, 2010; IUCN, 2021: Menon, 2021). One of the parasitic birds, the Common Cuckoo *Cuculus canorus*, has been used as indicator species in European countries not only due to its ecological responses but also the presence of their host species suggesting parasitic birds can also be used to monitor the diversity (Ducatez, 2014; Lee et al., 2014). Nevertheless, increase in bird species richness illustrates the presence of non-native species in the area while higher number of generalist bird species indicates habitat deterioration due to agricultural conversion (Gregory and van Strien, 2010; Morissette et al., 2019).

Conservation agencies and industry stakeholders of oil palm plantations should follow their counterparts in developed countries with respect to farmland biodiversity conservation. Annual farmland bird counts have helped scientists to improve farmland biodiversity conservation in the United Kingdom, France, Germany and other European countries as birds are more associated with citizens compared to other groups (Bretagnolle et al., 2018; Gregory and van Strien, 2010; Jerrentrup et al., 2017; The Royal Society for the Protection of Birds, 2021; Scholefield, 2011). Convention on Biological Diversity (CBD) and European countries highlighted the importance of indicators in managing biodiversity and monitoring land-use sustainability (Gregory et al., 2005).

CHAPTER 3

METHODOLOGY

3.1 Overall summary

The study to determine indicator bird species involved three main steps (Figure 3.1). Firstly, a comprehensive bird species list was compiled from 27 literature sources from the selected Southeast Asia sub-regions namely: Peninsular Malaysia, Borneo, the Philippines and Sumatra. Secondly, Similarity Percentages Analysis (SIMPER) analysis was performed on the bird species list to identify a list of indicator bird species by analysing the contribution of each species to the observed similarity between samples in each region. Lastly for Peninsular Malaysia, field surveys via point counts and opportunistic surveys were conducted to compare with the list of indicator bird species obtained from literature survey and simulate the certification process. In the following section, the two methods for acquiring data were first described and followed by both datasets analyses. Kirk et al. (2020) methods were followed who recommended combining literature review, opinion from the experts and empirical models as the best method to determine farmland bird indicators.

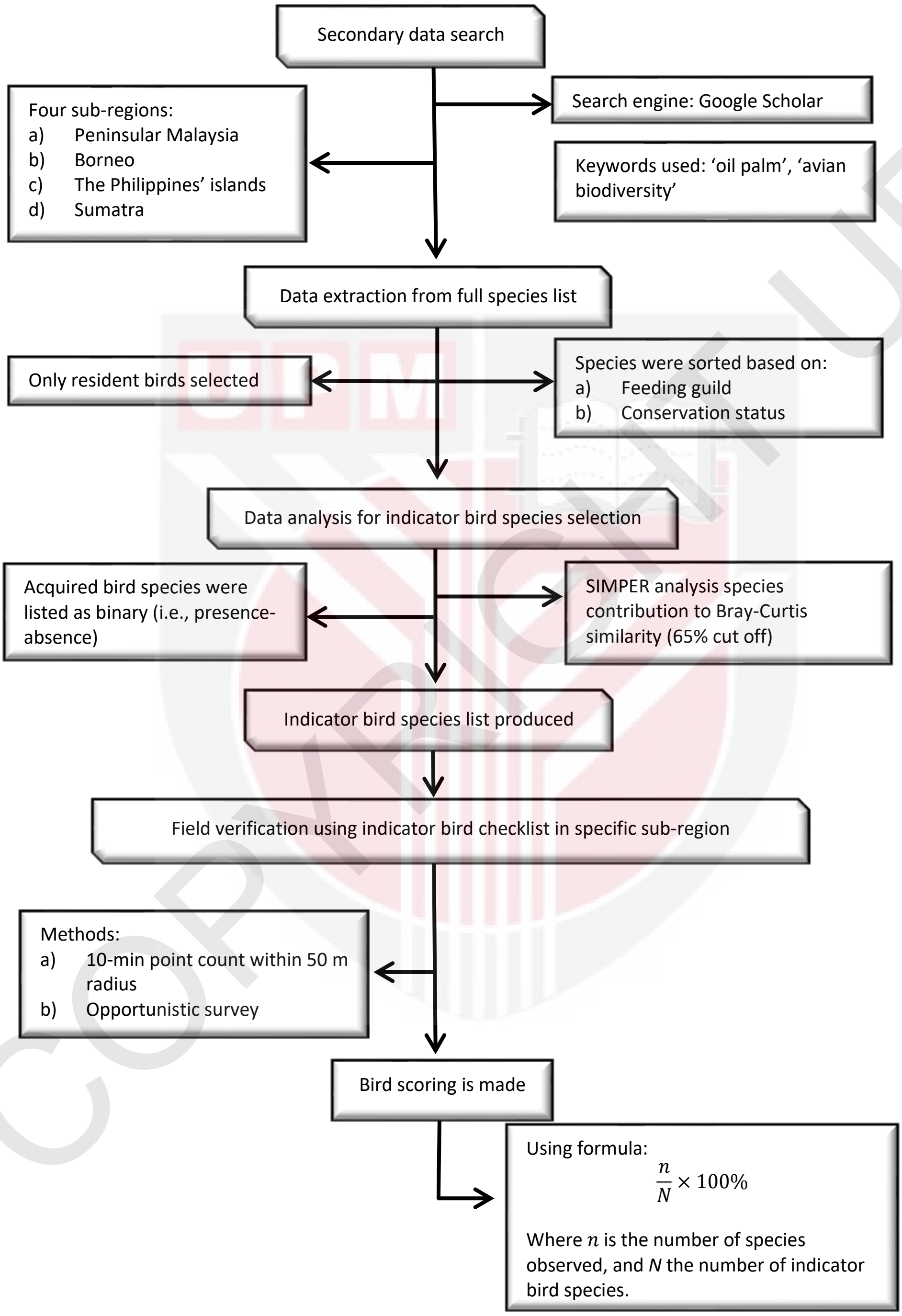

Figure 3.1 : Framework for producing indicator bird species list based on secondary data and applying the list in the field

3.2 Secondary data from literature research

Bird species list was gathered from published literature (i.e., 27 articles) focusing on oil palm avian biodiversity in four sub-regions of Southeast Asia (Figure 3.2, see Appendix A). The database acquired contained all literatures published online for the four subregions. The keywords 'oil palm' and 'avian biodiversity' were used and standardised for all sub-regions throughout data search, and all literatures cited in this study had the greatest number of articles found. Only resident bird species were included in the vetting process in which introduced species were selected also as they still contribute to the provisional of ecosystem services and regional biodiversity (Schlaepfer, 2018). Each identified species was distinguished and sorted based on feeding guilds, conservation and residency status based on local and regional field guides, handbooks and websites (e.g., International Union for Conservation of Nature (IUCN) Red List of Threatened Species, the Cornell Lab of Ornithology Birds of the World).

3.3 Field verification

For field verification, bird surveys were conducted via point count method at five study sites located within Peninsular Malaysia. These study sites were Rembau (2°37'13.08″ N, 102°03'27.88″ E), Banting (02°50′46.02″ N, 101°25′17.88″ E), Serdang (2°59′15.73″ N, 101°43′21.51″ E), Bangi (2°55′11.28″ N, 101°46′51.24″ E), Keratong (2°58′03.72″ N, 102°58′43.68″ E). Except for Keratong, all study sites were located on the West Coast of Peninsular Malaysia. Six, 12 and 60 sampling points were established in Banting, Keratong and Rembau, respectively. Bangi, Keratong and Rembau represented industrial plantations with area covering more than 50 hectares, while Banting and Serdang represented monoculture smallholdings with area covering more less 50 hectares. Sampling points were established >300 m apart to avoid bias in data collection (e.g., double count of the same individuals at multiple sampling points). During a 10-min observation period, all birds that were seen or heard within a 50 m radius were recorded. Flyover birds were excluded. Regional field guides (e.g., Jeyarajasingam, 2012) and websites (e.g., Xeno-canto.org) were referred to for species identification and verification. All bird counts were conducted between 0700 to 1100 hrs from February 2020 to February 2022.

Additionally, opportunistic bird surveys were conducted to simulate a feasible vetting method which could be used by auditors from organizations such as RSPO and MSPO for the certifying process. Opportunistic bird surveys were conducted in Bangi and Serdang in December 2021. The survey was conducted by walking along the main plantation pathways with no points established, assuming the organization audits would not practice point count method during the certification process. Birds that were seen and heard within a 50 m radius were recorded and compared with indicator species list from the published studies in Peninsular Malaysia. Flyover birds were excluded. Birds were immediately recorded as present based on a one-time occurrence.

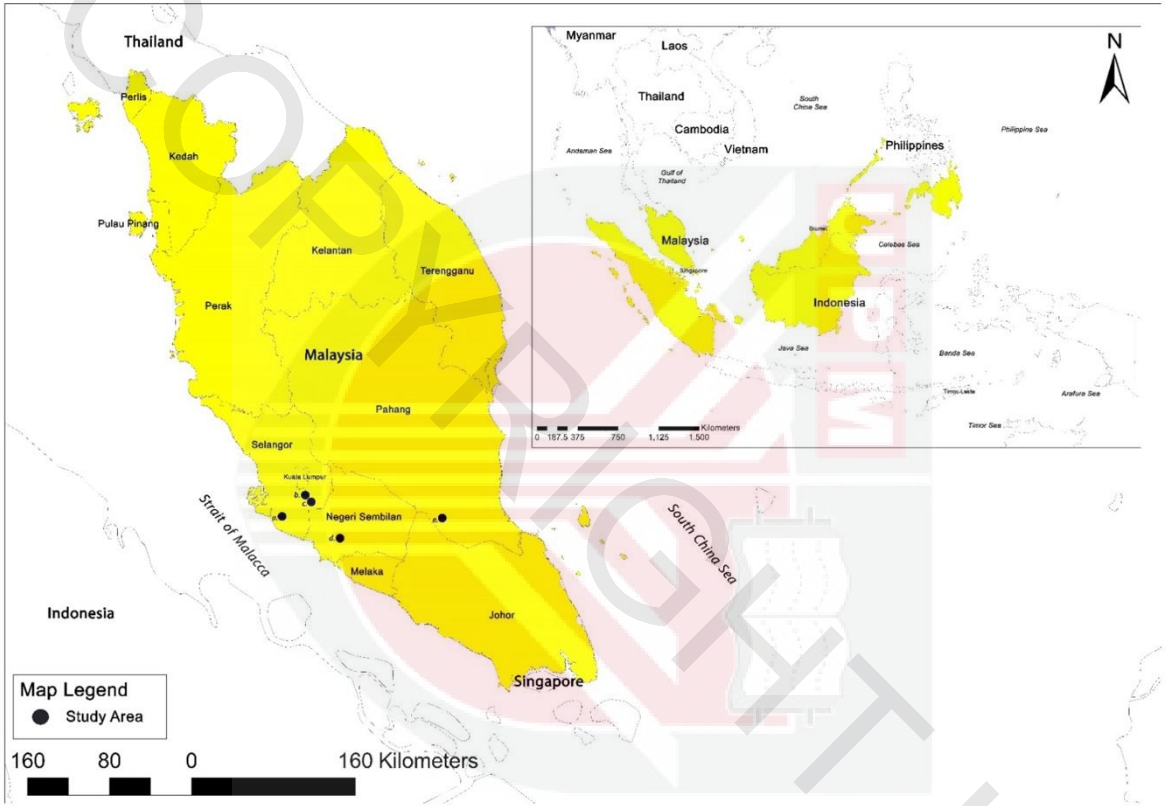

Figure 3.2 : Map of study regions where secondary data were gathered. Field verification was conducted at four oil palm plantations in Peninsular Malaysia

3.4 Data analysis

To identify indicator bird species, SIMPER was performed. Compiled bird species list in all focal four sub-regions acquired from the published literature was listed as binary (i.e., presence-absence). Abundance-based data was not analysed to minimise bias effects caused by different sampling methods used in these studies. For the field verification performed only in Peninsular Malaysia, the point count and opportunistic survey were analysed based on the number of bird observations per point.

Using Bray-Curtis measure of similarity, SIMPER analyses the contribution of each species to community assemblages. Species with greater contribution to the similarity is suggested to be good indicator species, due to their common occurrence within a certain area (Ricotta et al., 2021). In this study, a 65% cumulative cut off was set to select indicator species for each region. SIMPER was conducted in Primer-e version 7 (Clarke and Gorley, 2015).

CHAPTER 4

RESULTS

4.1 Indicator species identification

Based on the data provided by 27 published literatures, a total of 154, 110, 109, and 83 bird species were identified in oil palm production landscapes in Peninsular Malaysia, The Philippines, Borneo and Sumatra, respectively (see Appendix B). Each region had a unique assemblage of farmland bird species. However, some species were recorded in several regions (Table 4.1). The lists also showed that none of the species occurred in all four selected sub-regions, which correspond to studies by Jerrentrup et al. (2017), Whittingham et al. (2007) and Wretenberg et al. (2007) which show that diverse areas will have different bird species assemblages. The SIMPER analysis identified 20, 10, 12 and seven potential indicator bird species in Peninsular Malaysia, the Philippines, Borneo and Sumatra respectively (Table 4.1). All indicator bird species were listed as Least Concern (LC) by the IUCN except for the Javan Myna which was listed as Vulnerable (VU). The Javan Myna was consistently recorded in all previous studies conducted in Peninsular Malaysia where it is considered as an introduced species.

All regions (i.e., Sumatra and Peninsular Malaysia) recorded similar indicator bird species, but with different species occurrence. For instance, Zebra Dove and Yellow-vented Bulbul were recorded and persist well in all regions (species contribution = 3.97% - 10.67%) except Borneo and the Pied Fantail *Rhipidura javanica* was recorded in all regions (species contribution = 2.25% - 6.04%) except Sumatra, whereas the Spotted Dove *Streptopelia chinensis* was recorded in all regions (species contribution = 5.35% - 10.67%) except the Philippines. The White-breasted Waterhen *Amaurornis phoenicurus*, Oriental Magpie-robin and Little Egret *Egretta garzetta* were recorded in Peninsular Malaysia and Borneo (species contribution = 2.31% - 7.47%). The Asian Glossy Starling *Aplonis panayensis* was recorded in Peninsular Malaysia and the Philippines (species contribution = 3.37% - 6.04%). The White-throated Kingfisher was recorded in Peninsular Malaysia and Sumatra (species contribution = 3.37% - 10.67%). Lastly, Ashy Tailorbird *Orthotomus sepium* and Lesser Coucal *Centropus bengalensis* were recorded in Borneo and Sumatra (species contribution = 3.97% - 10.67%). Insectivorous birds made up majority of bird species across all regions with 41.2% of the total bird species compared to other bird groups such as frugivores (18.9%), carnivores (15.6%), omnivores (8.1%), granivores (7.1%), piscivores (5.8%) and nectarivores (3.3%) (Table 4.1).

Table 4.1 : Results of SIMPER similarity percentage using 65% cumulative cut off for Peninsular Malaysia, the Philippines, Borneo and Sumatra

Region	Species	Contrib.%	Cum.%	Feeding guild	Status of residency	IUCN status
Peninsular Malaysia	Spotted Dove	5.35	5.35	Granivore	R	LC
	Common Myna	3.97	9.32	Omnivore	R	LC
	Common Tailorbird	3.97	13.28	Insectivore	R	LC
	Javan Myna	3.97	17.25	Omnivore	R	VU
	Zebra Dove	3.97	21.22	Granivore	R	LC
	White-breasted Waterhen	3.97	25.19	Piscivore	R/M	LC
	Asian Glossy Starling	3.37	28.56	Frugivore	R	LC
	Black-naped Oriole	3.37	31.93	Frugivore	R	LC
	Crested Serpent-eagle	3.37	35.29	Carnivore	R	LC
	White-throated Kingfisher	3.37	38.66	Piscivore	R	LC
	Yellow-vented Bulbul	3.37	42.03	Omnivore	R	LC
	Oriental Magpie-robin	2.70	44.73	Insectivore	R	LC
	Collared Kingfisher	2.70	47.43	Piscivore	R	LC
	Common Flameback	2.31	49.74	Insectivore	R	LC
	Greater Coucal	2.31	52.05	Carnivore	R	LC
	Little Egret	2.31	54.36	Piscivore	M	LC
	Purple Heron	2.31	56.68	Piscivore	R/M	LC
	Red Junglefowl	2.31	58.99	Omnivore	R	LC
	Asian Koel	2.28	61.27	Frugivore	R/M	LC
	Pied Fantail	2.25	63.53	Insectivore	R	LC
	Asian Glossy Starling	6.04	6.04	Frugivore	R	LC
The Philippines	Common Emerald Dove	6.04	12.07	Granivore, frugivore	R	LC
	Eurasian Tree Sparrow	6.04	18.11	Granivore	R	LC
	Glossy Swiftlet	6.04	24.15	Insectivore	R	LC

Table 4.1 : Continued

	Olive-backed Sunbird	6.04	30.18	Nectarivore, frugivore, insectivore	R	LC
	Zebra Dove	6.04	36.22	Granivore	R	LC
	Pied Fantail	6.04	42.26	Insectivore	R	LC
	Pied Triller	6.04	48.29	Insectivore, frugivore	R	LC
	Striated Grassbird	6.04	54.33	Insectivore	R	LC
	White-bellied Munia	6.04	60.37	Granivore	R	LC
	Yellow-vented Bulbul	10.65	10.65	Omnivore	R	LC
Borneo	Spotted Dove	9.30	19.95	Granivore	R	LC
	White-breasted Waterhen	7.47	27.42	Piscivore	R/M	LC
	Rufous-tailed Tailorbird	4.91	32.34	Insectivore	R	LC
	Oriental Magpie-Robin	4.65	36.99	Insectivore	R	LC
	Yellow-bellied Prinia	4.65	41.65	Insectivore	R	LC
	Ashy Tailorbird	4.43	46.07	Insectivore	R	LC
	Dusky Munia	4.28	50.35	Granivore	R	LC
	Lesser Coucal	3.97	54.32	Insectivore	R	LC
	Crimson Sunbird	3.56	57.89	Insectivore, nectarivore	R	LC
	Little Egret	3.47	61.36	Piscivore	M	LC
	Pied Fantail	3.29	64.65	Insectivore	R	LC
	Ashy Tailorbird	10.67	10.67	Insectivore	R	LC
Sumatra	Spotted Dove	10.67	21.34	Granivore	R	LC
	White-throated Kingfisher	10.67	32.01	Piscivore	R	LC
	Yellow-vented Bulbul	10.67	42.68	Omnivore	R	LC
	Zebra Dove	6.77	49.45	Granivore	R	LC
	Sooty-headed Bulbul	6.54	55.99	Omnivore	R	LC
	Lesser Coucal	6.42	62.41	Insectivore	R	LC

LC: Least concern, VU: Vulnerable (according to IUCN species category), R: resident, M: migrant

4.2 Comparison and validation with field analysis

A total of 2156 individuals from 73 bird species from 35 families were recorded from Peninsular Malaysia (see Appendix C). The total number of individuals recorded for Bangi, Banting, Keratong, Rembau and Serdang were 139, 71, 120, 1788 and 38, respectively. Rembau recorded the highest number of bird species accounting for 66 species (90%), meanwhile Serdang recorded the least with 11 species (15%). Bangi, Banting and Keratong recorded 24, 16 and 18 bird species respectively. Only the Javan Myna and Long-tailed Parakeet *Psittacula longicauda* are classified as VU by the IUCN whereas the rest of the bird species are listed as LC (97%). The Javan Myna was observed in Bangi, Banting and Rembau with eight, 12 and 320 total individuals respectively. The Long-tailed Parakeet was observed only in Rembau with one total individual. Some of the bird species were observed only in one location. For example, Blue-winged Pitta *Pitta moluccensis* was found only in Rembau. The Black-thighed Falconet *Microhierax fringillarius*, Lineated Barbet *Megalaima lineata* and Hill Myna *Gracula religiosa* on the other hand, were observed only in Bangi. While Keratong recorded Cream-vented Bulbul *Pycnonotus simplex* and Purple Heron species which were absent in other locations. Insectivorous birds were the largest feeding guild found in this study accounting for 47% of the total individuals, followed by frugivores (19%), omnivores (9%), granivores (8%), piscivores and carnivores (7%), and nectarivores (3%).

When comparing the field data with the indicator species list from the previous step, Rembau showed the greatest similarity with 18 species (90%) observed out of 20 indicator species. Bangi recorded 14 species (70%) followed by Keratong, Banting and Serdang with 13 species (65%), ten species (50%) and nine species (45%) respectively (Table 4.2). However, the indicator species, Little Egret was not observed in any of the locations.

Table 4.2 : Point-count bird checklists based on indicator species in Peninsular Malaysia

Species	Bangi	Banting	Keratong	Rembau	Serdang
Spotted Dove	✓		✓	✓	
Common Myna			✓	✓	
Common Tailorbird	✓	✓	✓	✓	✓
Javan Myna	✓	✓		✓	
Zebra Dove	✓	✓	✓	✓	
White-breasted Waterhen	✓		✓	✓	
Asian Glossy Starling	✓			✓	✓
Black-naped Oriole	✓		✓	✓	
Crested Serpent-eagle	✓	✓	✓	✓	

Table 4.2 : Continued

White-throated Kingfisher	✓	✓	✓	✓	✓
Yellow-vented Bulbul	✓	✓	✓	✓	✓
Oriental Magpie-robin	✓	✓	✓	✓	✓
Collared Kingfisher				✓	✓
Common Flameback				✓	
Greater Coucal	✓	✓	✓	✓	✓
Little Egret					
Purple Heron			✓		
Red Junglefowl	✓	✓	✓	✓	✓
Asian Koel		✓		✓	✓
Pied Fantail	✓			✓	✓
Total species matched	14	10	13	18	9

Tick (✓): presence of bird species in the surveyed area

4.3 Comparison and validation with opportunistic surveys

Additional data from opportunistic surveys found ten (50%) and nine (45%) species in Bangi and Serdang respectively out of 20 indicator bird species identified for Peninsular Malaysia (Table 4.3). However, only six species were found to occur in both sites which are Common Tailorbird, Asian Glossy Starling, White-throated Kingfisher, Yellow-vented Bulbul, Oriental Magpie-robin and Red Junglefowl. Rufescent Prinia *Prinia rufescens*, Ashy Tailorbird and Lineated Barbet were also observed in both sites however these species are not on the indicator species list (see Appendix D). On the other hand, Zebra Dove, White-breasted Waterhen, Crested Serpent-eagle *Spilornis cheela*, Collared Kingfisher *Todiramphus chloris*, Common Flameback *Dinopium javanense*, Little Egret and Purple Heron were absent in both sites.

Table 4.3 : Opportunistic survey bird checklists for Bangi and Serdang based on indicator species in Peninsular Malaysia

Species	Bangi	Serdang
Spotted Dove	✓	
Common Myna	✓	
Common Tailorbird	✓	✓
Javan Myna		✓
Zebra Dove		

Table 4.3 : Continued

White-breasted Waterhen	✓	✓
Asian Glossy Starling		
Black-naped Oriole	✓	
Crested Serpent-eagle		
White-throated Kingfisher	✓	✓
Yellow-vented Bulbul	✓	✓
Oriental Magpie-robin	✓	✓
Collared Kingfisher		
Common Flameback		
Greater Coucal	✓	
Little Egret		
Purple Heron		
Red Junglefowl	✓	✓
Asian Koel		✓
Pied Fantail		✓
Total	10	9

Tick (✓): presence of bird species in the surveyed area

CHAPTER 5

DISCUSSION

5.1 Characteristics of farmland birds in oil palm production landscapes

Both generalist and specialist species were recorded across all study areas, with 10% of birds out of all species listed as indicator species found in all four regions. Species present at oil palm plantations are influenced by regional and site level characteristics. Oil palm production landscapes, particularly monoculture plantations are usually homogeneously structured and hence high abundance of common birds because they are usually associated with open habitat (Cotter et al., 2017). In contrast, coffee plantations recorded almost similar bird species diversity and richness as secondary forests due to shade trees management system practiced by the farmers (Alvarez-Alvarez et al., 2022). Coffee plants depend very highly on shades and hence majority of the farmers managed their plantations with polyculture system, representing coffee plantations with the highest habitat complexity and resulted in higher bird abundance than in other crops (Imron et al., 2022). The lack of undergrowth and canopy coverage led to higher number of generalist species in oil palm production landscapes (Yudea and Santosa, 2019), however previous studies have also highlighted the ability of oil palm agroecosystems as habitat for considerable number of specialist species including migratory, wetland and forest-dependent species (Azhar et al., 2011). In addition, different oil palm age stands have significant influenced on bird assemblages (i.e., species richness and occurrence of certain bird groups) (Atikah et al., 2019; Azhar et al., 2011; Yahya et al., 2017). For example, study by Azhar et al. (2011) and Ramlah et al. (2021) recorded greater bird species richness and abundance in immature oil palms compared to more mature oil palm stands (i.e., 6 – 10 years), however, mature oil palm supported more specialist bird species including bark probing insectivores. The low canopy cover in immature oil palm stands (<6 years) exposes ground to better sunlight thus enhances ground vegetation (Azhar et al., 2011; Sheldon, Styring and Hosner, 2010). Seeds produced by ground vegetation improve number of granivorous birds such as Zebra Dove in oil palm plantations as a potential seed disperser (Azhar et al., 2013; Tchoumbou et al., 2020). Introducing weeds and epiphytes also are a good way to attract insectivorous birds such as Yellow-bellied Prinia as these plants provide nesting sites (Desmier de Chenon and Susanto, 2006) besides increased in arthropods to be foraged by birds (Jambari et al., 2012; Jamian et al., 2017).

Farmland bird population trends are linked to various factors including spatial and temporal changes in agriculture (Jerrentrup et al., 2017). Thus, making farmland bird species as good indicator species for agro-ecological conditions. The findings indicate that conservation priority species were mostly absent from the 65% cut off in the SIMPER analyses. As such, uncommon species may not be a good candidate for indicator bird species (Morelli and Tryjanowski, 2017). This study also consistent with FBI surveys in the UK where only common species were recorded in farmlands instead of RTE species (The Royal Society for the Protection of Birds, 2021). The result suggests that the use of only RTE species as indicator species by the oil palm certifications should be revised. The absence of specialist species in agriculture landscape is also supported by coffee plantations in Mexico where large and strict frugivores were not recorded (Alvarez-Alvarez et al., 2022). Shifting the focus to more common associated biodiversity may boost oil palm yields and sustainability and provide better environments within and surrounding the plantations owing to the facts that common birds provide most of the vital ecosystem services (e.g., pest control) in agricultural landscapes (Denan et al., 2020; Kamarudin et al., 1996). Insectivorous birds play a crucial role in controlling leaf-eating pests in oil palm plantations, while barn owls contribute to the reduction of rodent populations (Kamarudin, Seman and Masri, 2019; Koh, 2008a).

Each region was found to have a unique set of indicator bird species due to geographical variations and endemism (Jerrentrup et al., 2017; Whittingham et al., 2007; Wretenberg et al., 2007). The Philippines recorded the second lowest number of indicator species compared to other regions. Factor such as island size increasing heterogeneity, may affects species occurrence in the Philippines Islands due to seclusion from mainland and geographic isolation between islands (Morelli and Tryjanowski, 2017). Borneo, on the other hand, recorded the second highest number of indicator bird species due to its large island area and hence high species richness. However, sampling efforts could also affect the number of species recorded in each region (Callaghan et al., 2018; Walther et al., 1995; Woolhouse, 1983). Only nine published studies were selected from Peninsular Malaysia, but it recorded the highest number of species and indicator bird species. This might be due to massive number of species recorded by Azhar et al. (2011), which is 107 species, where the rest of the published studies recorded an average of 30 species. Sumatra on the other hand is badly affected by wildlife trade and hence had smallest species list and indicator bird species recorded. The Oriental Magpie-robin and Yellow-vented Bulbul are among thousands of birds traded in Sumatra (Chng, Shepherd and Eaton, 2018; Harris et al., 2017).

The simplified habitat found in oil palm plantation agro ecosystems are likely to drive the higher number of least concern bird species in plantations. For instance, only Javan Myna in the indicator species list identified from the literature is listed, while point count analysis only recorded two listed species, the Javan Myna again and the Long-tailed Parakeet. The lack of suitable plants may have inhibited forest birds utilising oil palm plantations (Azhar et al., 2011; Peh et al., 2006). In addition, some locations had particularly low species richness, likely driven by the intensity of land use conversion such as in West Kalimantan oil palm plantations which had only 6% out of 214 bird's species sampled recorded (Simamora et al., 2021). Ocampo-Ariza et al. (2019) reported 1.36 ant-following bird species reduced with every 10% of forest cover loss in West Africa. There are a range of drivers for species richness decline including removal of trees creates canopy gaps which disturbs nesting of certain bird species (Lemelin et al., 2007; Simamora et al., 2021). In addition, pesticides applications have been found to further reduce animal population (Brühl and Zaller, 2019). Birds (Jambari et al., 2012) and insects are mainly affected due to the application of chemicals which are considered as one of the second most important contributors to population decline in agricultural plantations (Sánchez-Bayo and Wyckhuys, 2019).

Among the sites, Rembau had the highest bird species richness in point count and opportunistic surveys with 66 species and 18 species respectively. The oil palm plantations in Rembau occurred in patches and adjacent to residential areas, which likely increased the number of granivorous and frugivorous birds that inhabit or visit the plantations. Flowering and fruiting trees planted nearby might have encouraged bird species to visit the plantations (Azhar et al., 2015; Nurdiansyah et al., 2016). Callaghan et al. (2018) found that even several small green spaces were able to support high species richness. Serdang on the other hand, recorded the least number of species, at 11 and nine species using point count and opportunistic surveys respectively. Commercial buildings, lack of fruiting and flowering trees, and closeness to major roads likely affected bird assemblages in Serdang (Ashraf et al., 2018). However, the lower total area of oil palms in Serdang might also have contributed as there were less area available for bird observations. Only four locations were sampled in Serdang in contrast with Rembau which had 60 suitable locations. As a result, there is an obvious difference in sampling efforts that might influence bird species richness measures (Ferreira and Perbiche-Neves, 2021). Even so, Little Egret was not observed both in point count and opportunistic surveys despite being listed as indicator species. Absence of wetland areas such as mangroves and ponds in surveyed agro ecological matrixes are likely to create unfavourable environment for Little Egret to visit (Jeyarajasingam, 2012).

Insectivorous birds were found to persist well in oil palm agroecosystems compared to other feeding guilds due to the opened habitat and the associated high abundance of insects (Ramlah et al., 2021). For example, dragonflies foraged by Blue-throated Bee-eater *Merops viridis* are active in areas exposed to sunlight (Azhar et al., 2013). Similarly, the ant-following birds in Africa, and insectivorous birds in the Czech Republic have been observed with high abundances in open areas as opposed to in area of high forest cover (Horak et al., 2019; Kupsch et al., 2019). Amit et al. (2015) found nine Orders of insects in oil palm plantations and only one fruit plant species showing the potential for a high diversity in insectivorous birds than other feeding guilds in oil palm plantations. Interestingly, none of the frugivorous birds were listed as indicator species in Borneo and Sumatra. The Philippines and Peninsular Malaysia had no omnivores and nectarivores in the indicator list, respectively. Higher abundance of arboreal omnivores and terrestrial frugivores are highly associated with the proximity to forest patch (Azhar et al., 2013). In addition, creating non-oil palm vegetation at plantation edge boosts unique plant species such as Ficus spp. since plantation edge receives more light exposure and less disturbance from harvesters hence may be associated with more frugivorous birds (Jambari et al., 2012; Luke et al., 2019).

5.2 Farmland birds as indicators of oil palm sustainability

Industry stakeholders and conservation agencies in oil palm producing countries should follow their counterparts in Global North countries such as European countries with respect to farmland biodiversity conservation and their application as indicator species to support monitoring. Annual farmland bird counts have helped scientists to improve farmland biodiversity conservation in the United Kingdom (The Royal Society for the Protection of Birds, 2021), France (Bretagnolle et al., 2018), Germany (Jerrentrup et al., 2017) and the rest of the European countries (Scholefield, 2011). The CBD and European countries emphasize indicators as crucial part of biodiversity management and to monitor land-use sustainability (Gregory et al., 2005).

From the indicator species list produced and field validation, insectivores recorded the highest with 41.2% and 47% respectively, which indicate a wildlife-friendly farming system is possible to be implemented by oil palm growers. Rather than completely relying on expensive pesticides to improve oil palm yield, naturally occurring insectivorous birds can already help to reduce oil palm pests. For example, Yellow-vented Bulbul has been found to feed on African Oil Palm Weevil *Elaeidobius kamerunicus* as much as 80% of its diet in Malaysian oil palm (Amit et al., 2015). In Indonesia on the other hand, Ashy Tailorbird feeds on African Oil Palm Weevil as much as 75% of their diet, whereas Yellow-vented Bulbul consumes beetles, caterpillars and wasps (Desmier de Chenon and Susanto, 2006). This study also consistent with findings in India where insectivores were found to have the strongest correlation with agricultural land (Panda et al., 2021). While insectivorous birds provide pest control, lack of frugivores show poor oil palm management as it indicates lack of fruiting trees within or surrounding oil palm plantations. Frugivore which is the second biggest feeding guild in indicator list, act as pollinator and seed disperser for non-crop plants. Fruiting trees can be improved naturally with the help of frugivores in terms of associated biodiversity. For example, both sunbirds and spiderhunters were found to pollinate fruiting trees such as wild banana and durian (Yumoto, 2000; Ssali and Sheil, 2019). Carnivores, such as Crested Serpent-eagle and Greater Coucal, accounted third among all feeding guilds in indicator species list. Presence of carnivorous birds in oil palm plantations shows a healthy ecosystem where they feed on amphibians, reptiles as well as snails. Amphibians are very sensitive to chemicals thus the high abundance of frogs are due to low pesticide application while abundance of both amphibians and reptiles indicate presence of leaf litter in the plantation area (Cervantes-López, 2022; Zainudin et al., 2019).

Omnivorous birds, such as bulbuls and mynas, increase with the decrease of plant diversity as this feeding guild are often comprised of generalist species.

Omnivores may thrive better in open and deteriorating habitat as compared to other specialist species and hence lower abundance of omnivorous birds indicate healthy undergrowth and canopy coverage (Warren-Thomas et al., 2022; Yudea and Santosa, 2019). Granivores, such as doves, are a part of associated biodiversity in agriculture. They feed on seeds thus granivorous bird as one of the indicator birds is a sign of presence of ground vegetation in the area besides serving as seed dispersers (Azhar et al., 2013; Tchoumbou et al., 2020). Undergrowths such as legume crops are a good mechanism to enhance water and soil quality while reducing ground pressure thus granivorous birds are essential contributors in increasing undergrowth cover naturally (Nabara et al., 2021). Piscivores that feed on fish, frogs, crustaceans and aquatic insects indicate presence of water bodies in the plantations. Piscivorous birds rely heavily on water regimes that provide fitting habitat and food supply towards the species (Mohd-Taib, Mohd-Saleh and Rosli, 2020). Finally, nectarivores that contributed the least feeding guild in the indicator species list are not less any important as other feeding guilds. Nectarivorous birds, such as sunbirds, indicate presence of flowering plants as well as reflect canopy coverage based on total sunlight received in the area (Ng, 2020). Retaining non-crop patches between the plantations are also a good practice to maintain nectarivorous birds in the area (Salek et al., 2018; Warren-Thomas et al., 2022). Overall, the indicator species list managed to represent all important feeding guilds in oil palm production landscape to reflect a sustainable plantation.

A revised oil palm agri-environmental certification scheme could be implemented which includes evaluating farmland bird trends in the agricultural landscapes. Protecting farmland birds is critical for supporting a range of ecosystem services, in particular managing insect pest, as the number of insectivorous birds is high. Many of the species identified on the indicator list react rapidly to ecological changes (Siddig et al., 2016), are strongly dependant on food availability, and influenced by landscape and soil characteristics (Menon, 2021), hence make good indicators. Together with the knowledge of their feeding guilds (Gamero et al., 2017; Kirk et al., 2020), further studies need to be done on how food availability such as insect pest and their life stage (larvae/adult) influences the indicator bird species preferences in oil palm agro ecosystem.

In addition to the application to support agro ecosystem ecological health, a farmland indicator bird species approach can be used to support an Integrated Pest Management (IPM) in oil palm production landscapes. Insect defoliators such as bagworm (*Psychidae* spp.) and nettle caterpillar (*Limacodidae* spp.) are the major pests of oil palm in Malaysia and Indonesia, damaging its leaves and inhibiting tree growth (Wood, 1968). The absence of insectivorous birds causes higher herbivory rates in oil palm seedlings (Koh, 2008a) but according to Maas et al. (2015), birds prey on arthropod and lower the herbivory pest and leaf damage on young oil palms.

5.3 Conservation implications

High number of generalist species found in selected oil palm plantations indicates the importance of land-sharing strategy. The significant abundance of common bird species in agricultural land also shows the suitability of land-sharing strategy in oil palm plantations as common bird species have high spatial continuity and climate change adaptability (Amir, Noor and Hambali, 2015; Azhar et al., 2011; Green et al. 2005; Peh et al., 2006; Matson and Vitousek, 2006).

Sparing one land to accommodate wildlife conservation will only result in species intensification in which it will eventually threaten species composition as the spared forest will focus only on specialist birds (Fischer et al., 2008). With the absence of common species in the spared land, ecosystem structure will be imbalanced (Gregory and van Strien, 2010). Moreover, maintaining forest patches within oil palm plantations was found to positively affect arboreal omnivores, terrestrial frugivores and few of the forest-dependent species (Atikah et al., 2019; Azhar et al., 2013; Jambari et al., 2012).

Practicing wildlife-friendly farming also increases habitat complexity as opposed to monoculture system which lacking in various canopy layer (Qaim et al., 2020). Integrating land-sharing scheme in agricultural landscape will not only improve biodiversity, but the associated biodiversity within and surrounding the landscape benefits the farmers through ecological services such as pest control as well as regulation of microclimate and oil palm soil in the landscape (Anamulai et al., 2019; Denmead et al., 2017; Evans et al., 2011; Maas et al., 2015; Maine and Boyles, 2015). In contrast, land-sparing requires high amount of pesticides and fertilizer for optimum yield in which it involves greater amount of labour force and expenses (Fischer et al., 2008).

As for conclusion, the common bird species presence in bird indicator species highlight the urgent need to conserve farmland birds as well as the associated biodiversity. Both government and non-profit organizations should maximize their effort in creating awareness of land-sharing strategy to stakeholders and smallholders. Implementing the wildlife-friendly farming strategy in certification process is very much needed for the farmers to work synergistically towards the same objectives instead of focusing solely on maximizing yield (Kunz et al., 2019).

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusions

The prevalence of common species in the associated biodiversity is a potential indication for measuring the sustainability of oil palm plantations. Birds were chosen as indicators because of their rapid responsiveness to environmental changes, the ease with which they may be monitored, and the ecosystem services they provide to their habitat. A list of indicator bird species was developed for oil palm plantations in four Southeast Asian sub-regions: Peninsular Malaysia, Borneo, the Philippines, and Sumatra, using a combination of published studies and primary field data.

The concept of indicator bird species can help with land sharing and wildlife-friendly farming practices in oil palm plantations since production landscapes can be managed for conservation purposes. However, certification authorities have yet to use the notion as a proxy for ecosystem health in oil palm production settings. According to the findings of literature research, common farmland birds dominated oil palm agroecosystems and provided the greatest ecosystem services. As a result, common farmland birds must be prioritised as indicator species in assessing oil palm sustainability and establishing certification requirements. The results of the literature search demonstrate that indicator birds are strongly connected with geographical and endemism characteristics, with each region having its own unique set of indicator bird species. Thus, it is optimal to create an indicator list based on regional avian biodiversity data. Javan Myna, for example, was recorded at all sites in Peninsular Malaysia, but not in Borneo, the Philippines, or Sumatra. This study also found that insectivorous birds dominated oil palm agroecosystems compared to other feeding guilds due to the abundance of insects in open habitats and the scarcity of fruit plants (Amit et al., 2015; Ramlah et al., 2021). Frugivorous birds were not designated as indicator species in Borneo or Sumatra. In the Philippines, no omnivores were classified as indicators, while Peninsular Malaysia did not include nectarivores among its indicator species. The prevalence of arboreal omnivores and terrestrial frugivores is significantly associated with proximity to forest patches (Azhar et al., 2013).

Field verification in Peninsular Malaysia revealed that Rembau had the most similarity to the indicator species list, while Serdang had the lowest due to varying environments around the plantation. Oil palm plantations were scattered around Rembau, often near residential neighbourhoods. This proximity most likely resulted in an increase in the number of granivorous and frugivorous birds within or around the crops. The presence of commercial structures, the dearth of fruiting and flowering trees, and the closeness to major roadways may have all had an impact on the makeup of bird assemblages in Serdang. Annual farmland bird counts 72 involving the public (i.e., conservation science) and oil palm producers (i.e., smallholders and plantation corporations) are required to collect baseline data for developing effective farmland biodiversity conservation plans. The incorporation of the indicator species idea, which is focused on common bird species rather than RTE, into oil palm certification systems will help to boost oil palm environmental sustainability policies in terms of biodiversity conservation and ecosystem services. Shifting to oil palm polyculture management and GAP is critical to preventing additional declines in agricultural bird species diversity and abundance, particularly in conserving non-cropped portions within and around farmlands, as well as forest sections nearby. Oil palm farmers and stakeholders can also take examples from coffee plantation management systems, whereby farmers 1) integrated shade trees by planting multipurpose tree species in their farms, as coffee plants depend highly on shades for effective growth, 2) applied grass strip planting technique to bind the soil from runoff, 3) planted creeping legumes to obtain organic matter for soil fertility, 4) and used agricultural waste from livestock mulch to enhance soil quality (Alvarez-Alvarez et al., 2022; Imron et al., 2022; Kuswadi and Fitriani, 2021).

6.2 Limitations of the study

One of the caveats of this study is the unequal number of published studies representing each focal region and temporal changes between sampling locations. Increasing sampling efforts, and systematic sampling, supported by certification organisations could decrease these limitations and enhance the robustness of indicator species list. Oil palms stand age also hold different species composition at every level in which it was not taken into account in identifying indicator bird species (Azhar et al., 2013). However, this study aims to promote the indicator bird species concept into oil palm certification schemes hence detailed processes can be further carried out by the certification bodies according to the oil palm assemblages without the emphasis on RTE species.

6.3 Future research

To provide a robust bird indicator list, annual survey needs to be conducted to ensure updated bird species in keeping with the temporal and spatial scale with the involvement of plantation workers, local community and universities. Annual farmland bird counts have supported scientists in the UK, France, Germany, and the rest of Europe in improving sustainable farmland biodiversity (Bretagnolle et al., 2018; Gregory and van Strien, 2010; Jerrentrup et al., 2017; The Royal Society for the Protection of Birds, 2021; Scholefield, 2011). Oil palm smallholders and stakeholders should support the bird indicator species concept to be implemented in environmental sustainability assessment. The collaboration between the government and volunteers had made it easier to monitor farmland bird trends and had shown to be effective as done by the UK FBI, the European FBI and the Dutch FBI in which oil palm agencies and stakeholders should extend into oil palm landscape (The Royal Society for the Protection of Birds, 2021; Scholefield, 2011; Statistics Netherlands, 2021). Similar research approaches can be used to evaluate data from published studies in other regions with oil palm such as South American countries (e.g., Columbia, Brazil, Costa Rica) and can be extended to other animal taxa such as butterflies and bats. For example, butterflies have been found to be negatively affected by fertilization indicating butterflies as useful habitat indicator especially in agricultural landscape (Sharma et al., 2020). Whereas the presence of dead logs and shade cover have been found to be highly affected by bat diversity in coffee farms, hence suggesting bats may be a useful indicator species in agroecosystem, along with birds and butterflies (Huang et al., 2019). A study by Maas et al. (2015) shows predatory by bat species on arthropods in oil palm plantations lower pest and leaf damage on young oil palms. To improve current certification, biodiversity surveys for oil palm plantations should be conducted to assess indicator species list in oil palm plantations, for example, every 3-5 years. The field comparison simulating an oil palm audit demonstrated the potential suitability of the approach outlined in this paper.

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APPENDICES

Appendix A: Published literatures in selected sub-regions

Regions	Total Published Literature	Published Literatures
Peninsular Malaysia	9	Amir et al., 2015 Atiqah et al., 2019 Azhar et al., 2011 Azhar et al., 2014 Azman et al., 2011 Jambari et al., 2012 Peh et al., 2006 Razak et al., 2020 Tohiran et al., 2017
Borneo	10	Amit et al., 2014 Edwards et al., 2013 Gervais et al., 2012 Koh, 2008a Mitchell et al., 2018 Mohd-Azlan et al., 2019 Mulyani et al., 2018 Santosa & Sugiharti, 2018 Sheldon et al., 2010 Yudea & Santosa, 2019
The Philippines	3	Achondo et al., 2011 Bernardo, 2017 Cagod & Nuñeza, 2012
Sumatera	5	Denmead et al., 2017 Desmier de Chenon & Susanto, 2006 Erniwati et al., 2016 Erniwati & Santosa, 2019 Teuscher et al., 2015

Appendix B: Published species list of bird in oil palm plantations

Authors	Method	Species	Feeding Guild	Status of Residency	IUCN Status
Peninsular Malaysia					
Peh et al. (2006)	10 minutes point count	Rufous woodpecker *Celeus brachyurus*	Insectivore	R	LC
		Banded woodpecker *Picus miniaceus*	Insectivore	R	LC
		Checker-throated woodpecker *Picus mentalis*	Carnivore, insectivore	M	NT
		Buff-rumped woodpecker *Meiglyptes tristis*	Insectivore	R	LC
		Gold-whiskered barbet *Megalaima chrysopogon*	Frugivore	R	LC
		White-crowned hornbill *Berenicornis comatus*	Omnivore	R	EN
		Blue-eared kingfisher *Alcedo meninting*	Piscivore	R	LC
		Oriental dwarf kingfisher *Ceyx erithaca*	Insectivore	R	LC
		Red-bearded bee-eater *Nyctyornis amictus*	Insectivore	R	LC
		Indian cuckoo *Cuculus micropterus*	Insectivore	R	LC
		Banded bay cuckoo *Cacomantis sonneratii*	Insectivore	R	LC
		Square-tailed Drongo cuckoo *Surniculus lugubris*	Insectivore	R	LC

		Blue-rumped parrot *Psittinus cyanurus*	Frugivore	R	NT
		Blue-crowned hanging parrot *Psittinus cyanurus*	Frugivore	R	LC
		Long-tailed parakeet *Psittacula longicauda*	Frugivore	R	VU
		Emerald dove *Chalcophaps indica*	Granivore, frugivore	R	LC
		Little green pigeon *Treron olax*	Frugivore	R	LC
		Green imperial pigeon *Ducula aenea*	Frugivore	R	LC
		Blue-winged leafbird *Chloropsis cochinchinensis*	Omnivore	R	LC
		Greater racquet-tailed drongo *Dicrurus paradiseus*	Insectivore	R	LC
		Black-naped monarch *Hypothymis azurea*	Insectivore	R	LC
		White-rumped shama *Copsychus malabaricus*	Insectivore	R	LC
		Hill myna *Gracula religiosa*	Frugivore	R	LC
		Straw-headed bulbul *Pycnonotus zeylanicus*	Frugivore, granivore	R	CR
		Cream-vented bulbul *Pycnonotus simplex*	Frugivore, insectivore	R	LC
		Red-eyed bulbul *Pycnonotus brunneus*	Frugivore	R	LC
		Spectacled bulbul *Pycnonotus erythropthalmos*	Frugivore, insectivore	R	LC

		Streaked bulbul *Ixos malaccensis*	Frugivore, insectivore	R	NT
		Dark-necked tailorbird *Orthotomus atrogularis*	Insectivore	R	LC
		Abbott's babbler *Malacocincla abbotti*	Insectivore, carnivore	R	LC
		Pin-striped tit-babbler *Macronous gularis*	Insectivore	R	LC
		Crimson-breasted flowerpecker *Prionochilus percussus*	Frugivore	R	LC
		Orange-bellied flowerpecker *Dicaeum trigonostigma*	Frugivore	R	LC
		Plain flowerpecker *Dicaeum concolor*	Insectivore, frugivore	R	LC
		Scarlet-backed flowerpecker *Dicaeum cruentatum*	Frugivore	R	LC
		Ruby-cheeked sunbird *Anthreptes singalensis*	Insectivore, frugivore	R	LC
		Little spiderhunter *Arachnothera longirostra*	Nectarivore, insectivore	R	LC
		Grey-breasted spiderhunter *Arachnothera affinis*	Carnivore, insectivore	R	LC
Azhar et al. (2011)	Transect	Oriental Magpie-robin *Copsychus saularis*	Insectivore	R	LC
		Common Tailorbird *Orthotomus sutorius*	Insectivore	R	LC
		White-throated Kingfisher *Halcyon smyrnensis*	Insectivore, piscivore	R	LC

		Red Junglefowl *Gallus gallus*	Omnivore	R	LC
		Yellow-vented Bulbul *Pycnonotus goiavier*	Omnivore	R	LC
		Spotted Dove *Streptopelia chinensis*	Granivore	R	LC
		Ashy Tailorbird *Orthotomus sepium*	Insectivore	R	LC
		Pacific Swallow *Hirundo tahitica*	Insectivore	R	LC
		White-breasted Waterhen *Amaurornis phoenicurus*	Piscivore	R/M	LC
		Zebra Dove *Geopelia striata*	Granivore	R	LC
		Black-naped Oriole *Oriolus chinensis*	Frugivore	R	LC
		Javan Myna *Acridotheres javanicus*	Omnivore	R	VU
		Oriental Pied Hornbill *Anthracoceros albirostris*	Frugivore	R	LC
		Rhinoceros Hornbill *Buceros rhinoceros*	Frugivore	R	VU
		Blue-crowned Hanging Parrot *Psittinus cyanurus*	Frugivore	R	LC
		Long-tailed Parakeet *Psittacula longicauda*	Frugivore	R	VU
		Blue-eared Barbet *Megalaima australis*	Frugivore, insectivore	R	LC
		Coppersmith Barbet *Megalaima haemacephala*	Frugivore	R	LC

		Lineated Barbet *Megalaima lineata*	Frugivore	R	LC
		Scarlet-backed Flowerpecker *Dicaeum cruentatum*	Frugivore	R	LC
		Common Iora *Aegithina tiphia*	Insectivore	R	LC
		Rock Pigeon *Columba livia*	Granivore, frugivore	R	LC
		Green Imperial Pigeon *Ducula aenea*	Frugivore	R	LC
		Red Turtle-dove *Streptopelia tranquebarica*	Granivore	R	LC
		Thick-billed Pigeon *Treron curvirostra*	Frugivore	R	LC
		Pink-necked Green-pigeon *Treron vernans*	Frugivore	R	LC
		Olive-backed Sunbird *Nectarinia jugularis*	Nectarivore, frugivore, insectivore	R	LC
		Arctic Warbler *Phylloscopus borealis*	Insectivore	M	LC
		Striped Tit-Babbler *Macronous gularis*	Insectivore	R	LC
		Dark-necked Tailorbird *Orthotomus atrogularis*	Insectivore	R	LC
		Rufous-tailed Tailorbird *Orthotomus sericeus*	Insectivore	R	LC
		Yellow-bellied Prinia *Prinia flaviventris*	Insectivore	R	LC

		Rufescent Prinia *Prinia rufescens*	Insectivore	R	LC
		Rufous Woodpecker *Celeus brachyurus*	Insectivore	R	LC
		Common Flameback *Dinopium javanense*	Insectivore	R	LC
		Laced Woodpecker *Picus vittatus*	Insectivore	R	LC
		Streak-eared Bulbul *Pycnonotus blanfordi*	Frugivore, insectivore	R	LC
		Red-eyed Bulbul *Pycnonotus brunneus*	Frugivore	R	LC
		Olive-winged Bulbul *Pycnonotus plumosus*	Frugivore, insectivore	R	LC
		Cream-vented Bulbul *Pycnonotus simplex*	Frugivore, insectivore	R	LC
		Little Spiderhunter *Arachnothera longirostra*	Nectarivore, insectivore	R	LC
		Japanese Sparrowhawk *Accipiter gularis*	Carnivore	M	LC
		Crested Goshawk *Accipiter trivirgatus*	Carnivore	R	LC
		Greater Spotted Eagle *Aquila clanga*	Carnivore	M	VU
		Black Baza *Aviceda leuphotes*	Carnivore, insectivore	M	LC
		Black-thighed Falconet *Microhierax fringillarius*	Insectivore, carnivore	R	LC
		Crested Serpent-eagle *Spilornis cheela*	Carnivore	R	LC

		Changeable Hawk-eagle *Spizaetus cirrhatus*	Carnivore	R	LC
		Dusky Eagle Owl *Bubo coromandus*	Carnivore	R	LC
		Buffy Fish-owl *Ketupa ketupu*	Piscivore, carnivore	R	LC
		Brown Hawk-owl *Ninox scutulata*	Insectivore, carnivore	R/M	LC
		Collared-Scops Owl *Otus lettia*	Insectivore, carnivore	R	LC
		Spotted Wood-owl *Strix seloputo*	Carnivore	R	LC
		Barn Owl *Tyto alba*	Carnivore	R	LC
		Large-tailed Nightjar *Caprimulgus macrurus*	Insectivore	R	LC
		Barred Buttonquail *Turnix suscitator*	Granivore	R	LC
		Plaintive Cuckoo *Cacomantis merulinus*	Insectivore	R	LC
		Violet Cuckoo *Chrysococcyx xanthorhynchus*	Insectivore	R/M	LC
		Large Hawk-cuckoo *Cuculus sparveriodes*	Insectivore	R	LC
		Lesser Coucal *Centropus bengalensis*	Insectivore	R	LC
		Greater Coucal *Centropus sinensis*	Carnivore	R	LC
		Asian Koel *Eudynamys scolopaceus*	Frugivore	R/M	LC

		Green-billed Malkoha *Phaenicophaeus tristis*	Insectivore	R	LC
		Stork-billed Kingfisher *Halcyon capensis*	Piscivore	R	LC
		Collared Kingfisher *Halcyon chloris*	Piscivore	R	LC
		Red-throated Flycatcher *Ficedula parva*	Insectivore	M	LC
		Asian Brown Flycatcher *Muscicapa dauurica*	Insectivore	M	LC
		Asian Paradise-flycatcher *Terpsiphone paradisi*	Insectivore	R/M	LC
		Pied Fantail *Rhipidura javanica*	Insectivore	R	LC
		Forest Wagtail *Dendronanthus indicus*	Insectivore	M	LC
		Richard's Pipit *Anthus novaeseelandiae*	Insectivore	R	LC
		Chestnut-headed Bee-eater *Merops leschenaultia*	Insectivore	R	LC
		Blue-tailed Bee-eater *Merops philippinus*	Insectivore	R/M	LC
		Blue-throated Bee-eater *Merops viridis*	Insectivore	R/M	LC
		Oriental Dollarbird *Eurystomus orientalis*	Insectivore	R/M	LC
		Ashy Drongo *Dicrurus leucophaeus*	Insectivore, nectarivore	R	LC
		Slender-billed Crow *Corvus enca*	Omivore	R	LC

		Large-billed Crow *Corvus macrorhynchos*	Omnivore	R	LC
		House Crow *Corvus splendens*	Omnivore	R	LC
		Golden-bellied Gerygone *Gerygone sulphurea*	Insectivore	R	LC
		Brown Shrike *Lanius cristatus*	Insectivore	M	LC
		Tiger Shrike *Lanius tigrinus*	Insectivore	M	LC
		Baya Weaver *Ploceus philippinus*	Granivore	R	LC
		Javan Munia *Lonchura leucogastroides*	Granivore	R	LC
		White-headed Munia *Lonchura maja*	Granivore	R	LC
		Black-headed Munia *Lonchura malacca*	Granivore	R	LC
		Scaly-breasted Munia *Lonchura punctulata*	Granivore	R	LC
		White-rumped Munia *Lonchura striata*	Granivore	R	LC
		Asian Glossy Starling *Aplonis panayensis*	Frugivore	R	LC
		Jungle Myna *Acridotheres fuscus*	Omnivore	R	LC
		Common Myna *Acridotheres tristis*	Omnivore	R	LC
		Hill Myna	Frugivore	R	LC

		Gracula religiosa			
		Edible-nest Swiftlet *Aerodramus fuciphaga*	Insectivore	R	LC
		Asian Palm Swift *Cypsiurus balasiensis*	Insectivore	R	LC
		Barn Swallow *Hirundo rustica*	Insectivore	M	LC
		Pied Triller *Lalage nigra*	Insectivore, frugivore	R	LC
		Purple Heron *Ardea purpurea*	Piscivore, carnivore	R/M	LC
		Chinese Pond Heron *Ardeola bacchus*	Piscivore	M	LC
		Striated Heron *Butorides striatus*	Piscivore	R/M	LC
		Cattle Egret *Bubulcus ibis*	Piscivore	M	LC
		Little Egret *Egretta garzetta*	Piscivore	M	LC
		Cinnamon Bittern *Dupetor flavicollis*	Piscivore	R	LC
		Yellow Bittern *Ixobrychus sinensis*	Piscivore	R/M	LC
		Red-wattled Lapwing *Vanellus indicus*	Insectivore	R	LC
Azman et al. (2011)	Mist-netting & 10 minutes point count	Striated Heron *Butorides striatus*	Piscivore	R/M	LC
		Chinese Pond Heron	Piscivore	M	LC

		Ardeola bacchus			
		Javan Pond Heron *Ardeola speciosa*	Piscivore	R	LC
		Crested Serpent-eagle *Spilornis cheela*	Carnivore	R	LC
		Black Baza *Aviceda leuphotes*	Carnivore, insectivore	M	LC
		Red Junglefowl *Gallus gallus*	Omnivore	R	LC
		Spotted Dove *Streptopelia chinensis*	Granivore	R	LC
		Square-tailed Drongo Cuckoo *Surniculus lugubris*	Insectivore	R	LC
		Asian Koel *Eudynamys scolopaceus*	Frugivore	R/M	LC
		Black-bellied Malkoha *Rhopodytes diardi*	Insectivore	R	NT
		Raffles's Malkoha *Rhinortha chlorophaeus*	Insectivore	R	LC
		Green-billed Malkoha *Phaenicophaeus tristis*	Insectivore	R	LC
		Collared-Scops Owl *Otus lettia*	Insectivore, carnivore	R	LC
		Buffy Fish-owl *Ketupa ketupu*	Piscivore, carnivore	R	LC
		Little Swift *Apus affinis*	Insectivore	M	LC
		Stork-billed Kingfisher *Halcyon capensis*	Piscivore	R	LC

		White-throated Kingfisher *Halcyon smyrnensis*	Insectivore, piscviore	R	LC
		Blue-eared kingfisher *Alcedo meninting*	Insectivore	R	LC
		Buff-necked Woodpecker *Meiglyptes tukki*	Insectivore	R	NT
		Rufous Woodpecker *Celeus brachyurus*	Insectivore	R	LC
		Black-and-red Broadbill *Cymbirhynchus macrorhynchos*	Insectivore	R	LC
		Pacific Swallow *Hirundo tahitica*	Insectivore	R	LC
		Blue-winged Pitta *Pitta moluccensis*	Insectivore	R	LC
		Common Iora *Aegithina tiphia*	Insectivore	R	LC
		Red-eyed Bulbul *Pycnonotus brunneus*	Frugivore	R	LC
		Olive-winged Bulbul *Pycnonotus plumosus*	Frugivore, insectivore	R	LC
		Yellow-vented Bulbul *Pycnonotus goiavier*	Omnivore	R	LC
		Black-naped Oriole *Oriolus chinensis*	Frugivore	R	LC
		Common Tailorbird *Orthotomus sutorius*	Insectivore	R	LC
		Dark-necked Tailorbird *Orthotomus atrogularis*	Insectivore	R	LC
		Yellow-rumped Flycatcher *Ficedula zanthopygia*	Insectivore	M	LC

		Oriental Magpie Robin *Copsychus saularis*	Insectivore	R	LC
		White-rumped shama *Copsychus malabaricus*	Insectivore	R	LC
		Tickell's Blue Flycatcher *Cyornis tickelliae*	Insectivore	M	LC
		Pied Fantail *Rhipidura javanica*	Insectivore	R	LC
		Asian Glossy Starling *Aplonis panayensis*	Frugivore	R	LC
		Jungle Myna *Acridotheres fuscus*	Omnivore	R	LC
		Common Myna *Acridotheres tristis*	Omnivore	R	LC
		Little Spiderhunter *Arachnothera longirostra*	Nectarivore, insectivore	R	LC
Jambari et al. (2012)	Transect	Asian Brown Flycatcher *Muscicapa dauurica*	Insectivore	M	LC
		Asian Glossy Starling *Aplonis panayensis*	Frugivore	R	LC
		Asian Koel *Eudynamys scolopaceus*	Frugivore	R/M	LC
		Asian Paradise-flycatcher *Terpsiphone paradisi*	Insectivore	R/M	LC
		Ashy Tailorbird *Orthotomus sepium*	Insectivore	R	LC
		Barred Buttonquail *Turnix suscitator*	Granivore	R	LC

		Black-headed Munia *Lonchura malacca*	Granivore	R	LC
		Barn Owl *Tyto alba*	Carnivore	R	LC
		Baya Weaver *Ploceus philippinus*	Granivore	R	LC
		Black-naped Oriole *Oriolus chinensis*	Frugivore	R	LC
		Black-winged Kite *Elanus caeruleus*	Carnivore	R	LC
		Blue-throated Bee-eater *Merops viridis*	Insectivore	R/M	LC
		Blue-eared Barbet *Megalaima australis*	Frugivore, insectivore	R	LC
		Brown Shrike *Lanius cristatus*	Insectivore	M	LC
		Brahminy Kite *Haliastur indus*	Carnivore	R	LC
		Buffy Fish-owl *Ketupa ketupu*	Piscivore, carnivore	R	LC
		Changeable Hawk-eagle *Spizaetus cirrhatus*	Carnivore	R	LC
		Chinese Pond Heron *Ardeola bacchus*	Piscivore	M	LC
		Cinnamon Bittern *Dupetor flavicollis*	Piscivore	R	LC
		Collared Kingfisher *Halcyon chloris*	Piscivore	R	LC
		Common Myna *Acridotheres tristis*	Omnivore	R	LC

		Common Tailorbird *Orthotomus sutorius*	Insectivore	R	LC
		Common Flameback *Dinopium javanense*	Insectivore	R	LC
		Coppersmith Barbet *Megalaima haemacephala*	Frugivore	R	LC
		Cream-vented Bulbul *Pycnonotus simplex*	Frugivore, insectivore	R	LC
		Crested Serpent-eagle *Spilornis cheela*	Carnivore	R	LC
		Dark-necked Tailorbird *Orthotomus atrogularis*	Insectivore	R	LC
		Oriental Dollarbird *Eurystomus orientalis*	Insectivore	R/M	LC
		Dusky Eagle Owl *Bubo coromandus*	Carnivore	R	LC
		Greater Coucal *Centropus sinensis*	Carnivore	R	LC
		Green Imperial Pigeon *Ducula aenea*	Frugivore	R	LC
		Hill Myna *Gracula religiosa*	Frugivore	R	LC
		House Crow *Corvus splendens*	Omnivore	R	LC
		Javan Myna *Acridotheres javanicus*	Omnivore	R	VU
		Jungle Myna *Acridotheres fuscus*	Omnivore	R	LC
		Laced Woodpecker *Picus vittatus*	Insectivore	R	LC

		Large-tailed Nightjar *Caprimulgus macrurus*	Insectivore	R	LC
		Lesser Coucal *Centropus bengalensis*	Insectivore	R	LC
		Little Egret *Egretta garzetta*	Piscivore	M	LC
		Striated Heron *Butorides striatus*	Piscivore	R/M	LC
		Long-tailed Parakeet *Psittacula longicauda*	Frugivore	R	VU
		Olive-backed Sunbird *Nectarinia jugularis*	Nectarivore, frugivore, insectivore	R	LC
		Olive-winged Bulbul *Pycnonotus plumosus*	Frugivore, insectivore	R	LC
		Oriental Magpie Robin *Copsychus saularis*	Insectivore	R	LC
		Oriental Pied Hornbill *Anthracoceros albirostris*	Frugivore	R	LC
		Zebra Dove *Geopelia striata*	Granivore	R	LC
		Pied Fantail *Rhipidura javanica*	Insectivore	R	LC
		Pink-necked Green Pigeon *Treron vernans*	Frugivore	R	LC
		Plaintive Cuckoo *Cacomantis merulinus*	Insectivore	R	LC
		Purple Heron *Ardea purpurea*	Piscivore, carnivore	R/M	LC

		Red-eyed Bulbul *Pycnonotus brunneus*	Frugivore	R	LC
		Red-wattled Lapwing *Vanellus indicus*	Insectivore	R	LC
		Red Junglefowl *Gallus gallus*	Omnivore	R	LC
		Richard's Pipit *Anthus novaeseelandiae*	Insectivore	R	LC
		Rhinoceros Hornbill *Buceros rhinoceros*	Frugivore	R	VU
		Rock Pigeon *Columba livia*	Granivore, frugivore	R	LC
		Rufescent Prinia *Prinia rufescens*	Insectivore	R	LC
		Rufous Woodpecker *Celeus brachyurus*	Insectivore	R	LC
		Spotted Dove *Streptopelia chinensis*	Granivore	R	LC
		Spotted Wood-owl *Strix seloputo*	Carnivore	R	LC
		Scaly-breasted Munia *Lonchura punctulata*	Granivore	R	LC
		Slender-billed Crow *Corvus enca*	Omivore	R	LC
		Stork-billed Kingfisher *Halcyon capensis*	Piscivore	R	LC
		Streak-eared Bulbul *Pycnonotus blanfordi*	Frugivore, insectivore	R	LC
		Striped Tit-Babbler *Macronous gularis*	Insectivore	R	LC

		White-breasted Waterhen *Amaurornis phoenicurus*	Piscivore	R/M	LC
		White-headed Munia *Lonchura maja*	Granivore	R	LC
		White-rumped Munia *Lonchura striata*	Granivore	R	LC
		White-throated Kingfisher *Halcyon smyrnensis*	Insectivore, piscivore	R	LC
		Great Myna *Acridotheres grandis*	Insectivore	R	LC
		Yellow-bellied Prinia *Prinia flaviventris*	Insectivore	R	LC
		Yellow-vented Bulbul *Pycnonotus goiavier*	Omnivore	R	LC
Azhar et al. (2014)	10 minutes point count	Black-winged Kite *Elanus caeruleus*	Carnivore	R	LC
		Brahminy Kite *Haliastur indus*	Carnivore	R	LC
		Crested Serpent-eagle *Spilornis cheela*	Carnivore	R	LC
		Common Iora *Aegithina tiphia*	Insectivore	R	LC
		Collared Kingfisher *Halcyon chloris*	Piscivore	R	LC
		Stork-billed Kingfisher *Halcyon capensis*	Piscivore	R	LC
		White-throated Kingfisher *Halcyon smyrnensis*	Insectivore, piscivore	R	LC

		Purple Heron *Ardea purpurea*	Piscivore, carnivore	R/M	LC
		Little Egret *Egretta garzetta*	Piscivore	M	LC
		Red-wattled Lapwing *Vanellus indicus*	Insectivore	R	LC
		Ashy Tailorbird *Orthotomus sepium*	Insectivore	R	LC
		Common Tailorbird *Orthotomus sutorius*	Insectivore	R	LC
		Dark-necked Tailorbird *Orthotomus atrogularis*	Insectivore	R	LC
		Little Cuckoo-dove *Macropygia ruficeps*	Frugivore, granivore	R	LC
		Pink-necked Green Pigeon *Treron vernans*	Frugivore	R	LC
		Spotted Dove *Streptopelia chinensis*	Granivore	R	LC
		Zebra Dove *Geopelia striata*	Granivore	R	LC
		Oriental Dollarbird *Eurystomus orientalis*	Insectivore	R/M	LC
		House Crow *Corvus splendens*	Omnivore	R	LC
		Large-billed Crow *Corvus macrorhynchos*	Omnivore	R	LC
		Asian Koel *Eudynamys scolopaceus*	Frugivore	R/M	LC
		Greater Coucal *Centropus sinensis*	Carnivore	R	LC

		Chestnut Munia *Lonchura malacca*	Granivore	M	LC
		White-headed Munia *Lonchura maja*	Granivore	R	LC
		Barn Swallow *Hirundo rustica*	Insectivore	M	LC
		Pacific Swallow *Hirundo tahitica*	Insectivore	R	LC
		Paddyfield Pipit *Anthus rufulus*	Insectivore	R	LC
		Brown-throated Sunbird *Anthreptes malacensis*	Insectivore	R	LC
		Olive-backed Sunbird *Nectarinia jugularis*	Nectarivore, frugivore, insectivore	R	LC
		Purple-naped Sunbird *Hypogramma hypogrammicum*	Nectarivore, frugivore, insectivore	R	LC
		Black-naped Oriole *Oriolus chinensis*	Frugivore	R	LC
		Eurasian Tree Sparrow *Passer montanus*	Granivore	R	LC
		Red Junglefowl *Gallus gallus*	Omnivore	R	LC
		Common Flameback *Dinopium javanense*	Insectivore	R	LC
		Baya Weaver *Ploceus philippinus*	Granivore	R	LC
		Streaked Weaver *Ploceus manyar*	Granivore	M	LC

		Olive-winged Bulbul *Pycnonotus plumosus*	Frugivore, insectivore	R	LC
		Yellow-vented Bulbul *Pycnonotus goiavier*	Omnivore	R	LC
		White-breasted Waterhen *Amaurornis phoenicurus*	Piscivore	R/M	LC
		Pied Fantail *Rhipidura javanica*	Insectivore	R	LC
		Asian Glossy Starling *Aplonis panayensis*	Frugivore	R	LC
		Hill Myna *Gracula religiosa*	Frugivore	R	LC
		Common Myna *Acridotheres tristis*	Omnivore	R	LC
		Javan Myna *Acridotheres javanicus*	Omnivore	R	VU
		Oriental Magpie-robin *Copsychus saularis*	Insectivore	R	LC
Azhar et al. (2015)	Mist-netting	Oriental magpie robin *Copsychus saularis*	Insectivore	R	LC
		White-throated Kingfisher *Halcyon smyrnensis*	Insectivore, piscivore	R	LC
		Yellow-vented bulbul *Pycnonotus goiavier*	Omnivore	R	LC
		Zebra dove *Geopelia striata*	Granivore	R	LC
		Common tailorbird *Orthotomus sutorius*	Insectivore	R	LC

		Spotted dove *Streptopelia chinensis*	Granivore	R	LC
Amir, Noor and Hambali (2015)	10 minutes point count	Common Tailorbird *Orthotomus sutorius*	Insectivore	R	LC
		Common Myna *Acridotheres tristis*	Omnivore	R	LC
		Spotted Dove *Streptopelia chinensis*	Granivore	R	LC
		Oriental Magpie Robin *Copsychus saularis*	Insectivore	R	LC
		Zebra dove *Geopelia striata*	Granivore	R	LC
		White-breasted waterhen *Amaurornis phoenicurus*	Piscivore	R/M	LC
		Collared Kingfisher *Halcyon chloris*	Piscivore	R	LC
		Javan Myna *Acridotheres javanicus*	Omnivore	R	VU
		Chinese Pond Heron *Ardeola bacchus*	Piscivore	M	LC
Tohiran et al. (2017)	10 minutes point count	Black-winged Kite *Elanus caeruleus*	Carnivore	R	LC
		Crested Goshawk *Accipiter trivirgatus*	Carnivore	R	LC
		Crested Serpent-eagle *Spilornis cheela*	Carnivore	R	LC
		Collared Kingfisher *Halcyon chloris*	Piscivore	R	LC

		White-throated Kingfisher *Halcyon smyrnensis*	Insectivore, piscivore	R	LC
		Little Egret *Egretta garzetta*	Piscivore	M	LC
		Purple Heron *Ardea purpurea*	Piscivore, carnivore	R/M	LC
		Ashy Tailorbird *Orthotomus sepium*	Insectivore	R	LC
		Rufescent Prinia *Prinia rufescens*	Insectivore	R	LC
		Yellow-bellied Prinia *Prinia flaviventris*	Insectivore	R	LC
		Little Cuckoo-dove *Macropygia ruficeps*	Frugivore, granivore	R	LC
		Zebra Dove *Geopelia striata*	Granivore	R	LC
		Pink-necked Green-pigeon *Treron vernans*	Frugivore	R	LC
		Spotted Dove *Streptopelia chinensis*	Granivore	R	LC
		Oriental Dollarbird *Eurystomus orientalis*	Insectivore	R/M	LC
		House Crow *Corvus splendens*	Omnivore	R	LC
		Greater Coucal *Centropus sinensis*	Carnivore	R	LC
		White-headed Munia *Lonchura maja*	Granivore	R	LC
		Tiger Shrike *Lanius tigrinus*	Insectivore	M	LC

		Brown Shrike *Lanius cristatus*	Insectivore	M	LC
		Oriental Magpie-robin *Copsychus saularis*	Insectivore	R	LC
		Olive-backed Sunbird *Nectarinia jugularis*	Nectarivore, insectivore, frugivore	R	LC
		Black-naped Oriole *Oriolus chinensis*	Frugivore	R	LC
		Eurasian Tree Sparrow *Passer montanus*	Granivore	R	LC
		Red Junglefowl *Gallus gallus*	Omnivore	R	LC
		Common Flameback *Dinopium javanense*	Insectivore	R	LC
		Olive-winged Bulbul *Pycnonotus plumosus*	Frugivore, insectivore	R	LC
		Yellow-vented Bulbul *Pycnonotus goiavier*	Omnivore	R	LC
		White-breasted Waterhen *Amaurornis phoenicurus*	Piscivore	R/M	LC
		Pied Fantail *Rhipidura javanica*	Insectivore	R	LC
		Asian Glossy Starling *Aplonis panayensis*	Frugivore	R	LC
		Common Myna *Acridotheres tristis*	Omnivore	R	LC
		Javan Myna *Acridotheres javanicus*	Omnivore	R	VU

Atiqah et al. (2019)	Transect	Common Tailorbird *Orthotomus sutorius*	Insectivore	R	LC
		Rufous-tailed Tailorbird *Orthotomus sericeus*	Insectivore	R	LC
		Barn Owl *Tyto alba*	Carnivore	R	LC
		Crested Goshawk *Accipiter trivirgatus*	Carnivore	R	LC
		Black-winged Kite *Elanus caeruleus*	Carnivore	R	LC
		White-throated Kingfisher *Halcyon smyrnensis*	Insectivore, piscivore	R	LC
		Collared Kingfisher *Halcyon chloris*	Piscivore	R	LC
		Oriental Dwarf Kingfisher *Ceyx erithaca*	Insectivore	R	LC
		Little Egret *Egretta garzetta*	Piscivore	M	LC
		Striated Heron *Butorides striatus*	Piscivore	R/M	LC
		Yellow Bittern *Ixobrychus sinensis*	Piscivore	R/M	LC
		Purple Heron *Ardea purpurea*	Piscivore, carnivore	R/M	LC
		Spotted Dove *Streptopelia chinensis*	Granivore	R	LC
		Pink-necked Green-pigeon *Treron vernans*	Frugivore	R	LC

		Rock Pigeon *Columba livia*	Granivore, frugivore	R	LC
		Emerald Dove *Chalcophaps indica*	Granivore, frugivore	R	LC
		Zebra Dove *Geopelia striata*	Granivore	R	LC
		Oriental Dollarbird *Eurystomus orientalis*	Insectivore	R/M	LC
		Large-billed Crow *Corvus macrorhynchos*	Omnivore	R	LC
		Slender-billed Crow *Corvus enca*	Omivore	R	LC
		Lesser Coucal *Centropus bengalensis*	Insectivore	R	LC
		Greater Coucal *Centropus sinensis*	Carnivore	R	LC
		Asian Koel *Eudynamys scolopaceus*	Frugivore	R/M	LC
		Plaintive Cuckoo *Cacomantis merulinus*	Insectivore	R	LC
		White-rumped Munia *Lonchura striata*	Granivore	R	LC
		Crested Serpent-eagle *Spilornis cheela*	Carnivore	R	LC
		Brown Shrike *Lanius cristatus*	Insectivore	M	LC
		Tiger Shrike *Lanius tigrinus*	Insectivore	M	LC
		Blue-tailed Bee-eater *Merops philippinus*	Insectivore	R/M	LC

		Purple-throated Sunbird *Leptocoma sperata*	Nectarivore	M	LC
		Purple-naped Sunbird *Hypogramma hypogrammicum*	Nectarivore, frugivore, insectivore	R	LC
		Little Spiderhunter *Arachnothera longirostra*	Nectarivore, insectivore	R	LC
		Black-naped Oriole *Oriolus chinensis*	Frugivore	R	LC
		Common Flameback *Dinopium javanense*	Insectivore	R	LC
		Yellow-vented Bulbul *Pycnonotus goiavier*	Omnivore	R	LC
		Buff-vented Bulbul *Iole olivacea*	Frugivore	R	NT
		White-breasted Waterhen *Amaurornis phoenicurus*	Piscivore	R/M	LC
		Pied Fantail *Rhipidura javanica*	Insectivore	R	LC
		Buffy Fish-owl *Ketupa ketupu*	Piscivore, carnivore	R	LC
		Javan Myna *Acridotheres javanicus*	Omnivore	R	VU
		Asian Glossy Starling *Aplonis panayensis*	Frugivore	R	LC
		Red-wattled Lapwing *Vanellus indicus*	Insectivore	R	LC
Razak et al. (2020)	10 minutes point count	Eurasian Tree Sparrow *Passer montanus*	Granivore	R	LC

		Javan Myna *Acridotheres javanicus*	Omnivore	R	VU
		Zebra Dove *Geopelia striata*	Granivore	R	LC
		Brown-throated Sunbird *Anthreptes malacensis*	Insectivore	R	LC
		Common Myna *Acridotheres tristis*	Omnivore	R	LC
		Spotted Dove *Streptopelia chinensis*	Granivore	R	LC
		Yellow-vented Bulbul *Pycnonotus goiavier*	Omnivore	R	LC
		White-throated Kingfisher *Halcyon smyrnensis*	Insectivore, piscivore	R	LC
		Brahminy Kite *Haliastur indus*	Carnivore	R	LC
		House Crow *Corvus splendens*	Omnivore	R	LC
		Common Tailorbird *Orthotomus sutorius*	Insectivore	R	LC
		Asian Glossy Starling *Aplonis panayensis*	Frugivore	R	LC
		Asian Koel *Eudynamys scolopaceus*	Frugivore	R/M	LC
		Greater Coucal *Centropus sinensis*	Carnivore	R	LC
		Purple-naped Sunbird *Hypogramma hypogrammicum*	Nectarivore, frugivore, insectivore	R	LC

		Black-naped Oriole *Oriolus chinensis*	Frugivore	R	LC
		Olive-backed Sunbird *Nectarinia jugularis*	Nectarivore, frugivore, insectivore	R	LC
		Blue-throated Bee-eater *Merops viridis*	Insectivore	R/M	LC
		Brown Shrike *Lanius cristatus*	Insectivore	M	LC
		Tiger Shrike *Lanius tigrinus*	Insectivore	M	LC
		Emerald Dove *Chalcophaps indica*	Granivore, frugivore	R	LC
		Common Flameback *Dinopium javanense*	Insectivore	R	LC
		Crested Serpent-eagle *Spilornis cheela*	Carnivore	R	LC
		White-breasted Waterhen *Amaurornis phoenicurus*	Piscivore	R/M	LC
		Red Junglefowl *Gallus gallus*	Omnivore	R	LC
		Red-wattled Lapwing *Vanellus indicus*	Insectivore	R	LC
		Ashy Tailorbird *Orthotomus sepium*	Insectivore	R	LC
		Edible-nest Swiftlet *Aerodramus fuciphaga*	Insectivore	R	LC
		Stork-billed Kingfisher *Halcyon capensis*	Piscivore	R	LC

		Blue-eared Kingfisher *Alcedo meninting*	Piscivore	R	LC
		Purple Heron *Ardea purpurea*	Piscivore, carnivore	R/M	LC
		Little Egret *Egretta garzetta*	Piscivore	M	LC
		Long-tailed Parakeet *Psittacula longicauda*	Frugivore	R	VU
Sumatra					
Chenon & Susanto (2006)	Transect	Black-shouldered Kite *Elanus axillaris*	Carnivore	M	LC
		Crested Serpent-eagle *Spilornis cheela*	Carnivore	R	LC
		Collared Kingfisher *Halcyon chloris*	Piscivore	R	LC
		White-throated Kingfisher *Halcyon smyrnensis*	Insectivore, piscivore	R	LC
		Grey Heron *Ardea cinerea*	Piscivore	R	LC
		Large Woodshrike *Tephrodornis virgatus*	Insectivore	R	LC
		Zebra Dove *Geopelia striata*	Granivore	R	LC
		Spotted Dove *Streptopelia chinensis*	Granivore	R	LC
		Chestnut-Winged Cuckoo *Clamator coromandus*	Insectivore	R	LC

		Lesser Coucal *Centropus bengalensis*	Insectivore	R	LC
		Greater Coucal *Centropus sinensis*	Carnivore	R	LC
		Bronzed Drongo *Dicrurus aeneus*	Insectivore	R	LC
		Long-Tailed Shrike *Lanius schach*	Insectivore, carnivore	R	LC
		Tiger Shrike *Lanius tigrinus*	Insectivore	M	LC
		Blue-tailed Bee-eater *Merops philippinus*	Insectivore	R/M	LC
		Richard's Pipit *Anthus novaeseelandiae*	Insectivore	R	LC
		Forest Wagtail *Dendronanthus indicus*	Insectivore	M	LC
		Grey Wagtail *Motacilla cinerea*	Insectivore	R	LC
		Great Tit *Parus major*	Insectivore	R	LC
		White-headed Munia *Lonchura maja*	Granivore	R	LC
		Yellow-vented Bulbul *Pycnonotus goiavier*	Omnivore	R	LC
		White-breasted Waterhen *Amaurornis phoenicurus*	Piscivore	R/M	LC
		Javan Myna *Acridotheres javanicus*	Omnivore	R	VU
		Common Myna *Acridotheres tristis*	Omnivore	R	LC

		Ashy Tailorbird *Orthotomus sepium*	Insectivore	R	LC
		Black-throated Prinia *Prinia atrogularis*	Insectivore	M	LC
		Yellow-bellied Prinia *Prinia flaviventris*	Insectivore	R	LC
		Barred Buttonquail *Turnix suscitator*	Granivore	R	LC
		Oriental Magpie Robin *Copsychus saularis*	Insectivore	R	LC
Teuscher et al. (2015)	15 minutes point count	Green Iora *Aegithina viridissima*	Insectivore	R	LC
		Common Iora *Aegithina tiphia*	Insectivore	R	LC
		Crimson Sunbird *Aethopyga siparaja*	Insectivore, nectarivore	R	LC
		White-breasted Waterhen *Amaurornis phoenicurus*	Piscivore	R/M	LC
		Brown-throated Sunbird *Anthreptes malacensis*	Insectivore	R	LC
		White-breasted Woodswallow *Artamus leucorhynchus*	Insectivore	R	LC
		Rufous Woodpecker *Celeus brachyurus*	Insectivore	R	LC
		Lesser Coucal *Centropus bengalensis*	Insectivore	R	LC
		Greater Coucal *Centropus sinensis*	Carnivore	R	LC

		Emerald Dove *Chalcophaps indica*	Granivore, frugivore	R	LC
		Buff-spotted Flameback *Chrysocolaptes lucidus*	Insectivore	M	LC
		Golden-headed Cisticola *Cisticola exilis*	Insectivore	R	LC
		Scarlet-backed Flowerpecker *Dicaeum cruentatum*	Frugivore	R	LC
		Orange-bellied Flowerpecker *Dicaeum trigonostigma*	Frugivore	R	LC
		Red junglefowl *Gallus gallus*	Omnivore	R	LC
		Collared Kingfisher *Halcyon chloris*	Piscivore	R	LC
		White-throated Kingfisher *Halcyon smyrnensis*	Insectivore, piscivore	R	LC
		Barn Swallow *Hirundo rustica*	Insectivore	M	LC
		White-bellied Munia *Lonchura leucogastra*	Granivore	R	LC
		Black-faced Munia *Lonchura molucca*	Granivore, insectivore	R	LC
		Scaly-breasted Munia *Lonchura punctulata*	Granivore	R	LC
		Blue-crowned Hanging-parrot *Psittinus cyanurus*	Frugivore	R	LC
		Coppersmith Barbet *Megalaima haemacephala*	Frugivore	R	LC
		Dark-necked Tailorbird *Orthotomus atrogularis*	Insectivore	R	LC

		Ashy Tailorbird *Orthotomus sepium*	Insectivore	R	LC
		Rufous-tailed Tailorbird *Orthotomus sericeus*	Insectivore	R	LC
		Bar-winged Prinia *Prinia familiaris*	Insectivore	R	NT
		Yellow-bellied Prinia *Prinia flaviventris*	Insectivore	R	LC
		Sooty-headed Bulbul *Pycnonotus aurigaster*	Omnivore	R	LC
		Yellow-vented Bulbul *Pycnonotus goiavier*	Omnivore	R	LC
		Olive-winged Bulbul *Pycnonotus plumosus*	Frugivore, insectivore	R	LC
		Pied Fantail *Rhipidura javanica*	Insectivore	R	LC
		Spotted Dove *Streptopelia chinensis*	Granivore	R	LC
Erniwati et al. (2016)	Transect	Bar-winged Prinia *Prinia familiaris*	Insectivore	R	NT
		Yellow-vented Bulbul *Pycnonotus goiavier*	Omnivore	R	LC
		Sooty-headed Bulbul *Pycnonotus aurigaster*	Omnivore	R	LC
		Spotted Dove *Streptopelia chinensis*	Granivore	R	LC
		Ashy Tailorbird *Orthotomus sepium*	Insectivore	R	LC

		White-throated Kingfisher *Halcyon smyrnensis*	Insectivore, piscivore	R	LC
		Lesser Coucal *Centropus bengalensis*	Insectivore	R	LC
		Zebra Dove *Geopelia striata*	Granivore	R	LC
		Glossy Swiftlet *Collocalia esculenta*	Insectivore	R	LC
		Pacific Swallow *Hirundo tahitica*	Insectivore	R	LC
		Long-tailed Parakeet *Psittacula longicauda*	Frugivore	R	VU
		Olive-backed Sunbird *Nectarinia jugularis*	Nectarivore, frugivore, insectivore	R	LC
		Collared Kingfisher *Halcyon chloris*	Piscivore	R	LC
		Changeable Hawk-eagle *Spizaetus cirrhatus*	Carnivore	R	LC
		Black-winged Kite *Elanus caeruleus*	Carnivore	R	LC
		Crested Serpent-eagle *Spilornis cheela*	Carnivore	R	LC
		White-crowned Hornbill *Berenicornis comatus*	Omnivore	R	EN
		Cattle Egret *Bubulcus ibis*	Piscivore	M	LC
		Rhinoceros Hornbill *Buceros rhinoceros*	Frugivore	R	VU

		Barn Owl *Tyto alba*	Carnivore	R	LC
Denmead et al. (2017)	48h automated sound recorder	Green Iora *Aegithina viridissima*	Insectivore	R	LC
		Little Spiderhunter *Arachnothera longirostra*	Nectarivore, insectivore	R	LC
		Plaintive Cuckoo *Cacomantis merulinus*	Insectivore	R	LC
		Banded bay cuckoo *Cacomantis sonneratii*	Insectivore	R	LC
		Scarlet-backed flowerpecker *Dicaeum cruentatum*	Frugivore	R	LC
		Orange-bellied flowerpecker *Dicaeum trigonostigma*	Frugivore	R	LC
		Oriental Dollarbird *Eurystomus orientalis*	Insectivore	R/M	LC
		Zebra Dove *Geopelia striata*	Granivore	R	LC
		White-throated Kingfisher *Halcyon smyrnensis*	Insectivore, piscivore	R	LC
		Purple-naped Sunbird *Hypogramma hypogrammicum*	Nectarivore, frugivore, insectivore	R	LC
		Striped Tit-Babbler *Macronous gularis*	Insectivore	R	LC
		Buff-necked Woodpecker *Meiglyptes tukki*	Insectivore	R	NT
		Rufous Woodpecker	Insectivore	R	LC

		Celeus brachyurus			
		Dark-necked tailorbird *Orthotomus atrogularis*	Insectivore	R	LC
		Ashy Tailorbird *Orthotomus sepium*	Insectivore	R	LC
		Rufous-tailed Tailorbird *Orthotomus sericeus*	Insectivore	R	LC
		Bar-winged Prinia *Prinia familiaris*	Insectivore	R	NT
		Yellow-bellied Prinia *Prinia flaviventris*	Insectivore	R	LC
		Blue-rumped parrot *Psittinus cyanurus*	Frugivore	R	NT
		Black-headed Bulbul *Pycnonotus atriceps*	Frugivore	R	LC
		Sooty-headed Bulbul *Pycnonotus aurigaster*	Omnivore	R	LC
		Grey-bellied Bulbul *Pycnonotus cyaniventris*	Frugivore	R	NT
		Yellow-vented Bulbul *Pycnonotus goiavier*	Omnivore	R	LC
		Olive-winged Bulbul *Pycnonotus plumosus*	Frugivore, insectivore	R	LC
		Rufous Piculet *Sasia abnormis*	Insectivore	R	LC
		Spotted Dove *Streptopelia chinensis*	Granivore	R	LC
		Collared Kingfisher *Halcyon chloris*	Piscivore	R	LC

Erniwati & Santosa (2019)	Transect	Red Junglefowl *Gallus gallus*	Omnivore	R	LC
		Cinnamon Bittern *Dupetor flavicollis*	Piscivore	R	LC
		Long-Tailed Shrike *Lanius schach*	Insectivore, carnivore	R	LC
		Scaly-breasted Munia *Lonchura punctulata*	Granivore	R	LC
		Lesser Coucal *Centropus bengalensis*	Insectivore	R	LC
		Brown-throated Sunbird *Anthreptes malacensis*	Insectivore	R	LC
		Olive-backed Sunbird *Nectarinia jugularis*	Nectarivore, frugivore, insectivore	R	LC
		Large-tailed Nightjar *Caprimulgus macrurus*	Insectivore	R	LC
		Grey Heron *Ardea cinerea*	Piscivore	R	LC
		White-throated Kingfisher *Halcyon smyrnensis*	Insectivore, piscivore	R	LC
		Ashy Tailorbird *Orthotomus sepium*	Insectivore	R	LC
		Rufous-tailed Tailorbird *Orthotomus sericeus*	Insectivore	R	LC
		Sooty-headed Bulbul *Pycnonotus aurigaster*	Omnivore	R	LC
		Brahminy Kite *Haliastur indus*	Carnivore	R	LC

		White-breasted Waterhen *Amaurornis phoenicurus*	Piscivore	R/M	LC
		White-breasted Woodswallow *Artamus leucorhynchus*	Insectivore	R	LC
		Pied Fantail *Rhipidura javanica*	Insectivore	R	LC
		Yellow-vented Bulbul *Pycnonotus goiavier*	Omnivore	R	LC
		Yellow-bellied Prinia *Prinia flaviventris*	Insectivore	R	LC
		Zebra Dove *Geopelia striata*	Granivore	R	LC
		Small Blue Kingfisher *Alcedo coerulescens*	Piscivore	R	LC
		Blue-eared Kingfisher *Alcedo meninting*	Piscivore	R	LC
		Golden-bellied Gerygone *Gerygone sulphurea*	Insectivore	R	LC
		Spotted Dove *Streptopelia chinensis*	Granivore	R	LC
		Cave Swiftlet *Collocalia linchi*	Insectivore	R	LC
The Philippines					
Achondo et al. (2011)	Mist-netting & transect	Glossy Swiftlet *Collocalia esculenta*	Insectivore	R	LC
		Common Emerald Dove *Chalcophaps indica*	Granivore, frugivore	R	LC

		Zebra dove *Geopelia striata*	Granivore	R	LC
		Collared Kingfisher *Halcyon chloris*	Piscivore	R	LC
		White-throated Kingfisher *Halcyon smyrnensis*	Insectivore, piscivore	R	LC
		Plaintive Cuckoo *Cacomantis merulinus*	Insectivore	R	LC
		Philippine Coucal *Centropus viridis*	Insectivore	R	LC
		Asian Glossy Starling *Aplonis panayensis*	Frugivore	R	LC
		White-breasted Woodswallow *Artamus leucorhynchus*	Insectivore	R	LC
		Oriental Magpie Robin *Copsychus saularis*	Insectivore	R	LC
		Large-billed Crow *Corvus macrorhynchos*	Omnivore	R	LC
		Mangrove Blue Flycatcher *Cyornis rufigastra*	Insectivore	R	LC
		Red-keeled Flowerpecker *Dicaeum australe*	Nectarivore, frugivore	R	LC
		Pied Triller *Lalage nigra*	Insectivore, frugivore	R	LC
		Brown Shrike *Lanius cristatus*	Insectivore	M	LC
		White-bellied Munia *Lonchura leucogastra*	Granivore	R	LC
		Black-headed Munia *Lonchura malacca*	Granivore	R	LC

Cagod & Nuñeza (2012)	Mist-netting & transect	Brown-tit Babbler *Macronous striaticeps*	Insectivore	R	LC
		Striated Grassbird *Megalurus palustris*	Insectivore	R	LC
		Olive-backed Sunbird *Nectarinia jugularis*	Nectarivore, frugivore, insectivore	R	LC
		Eurasian Tree Sparrow *Passer montanus*	Granivore	R	LC
		Yellow-vented Bulbul *Pycnonotus goiavier*	Omnivore	R	LC
		Pied Fantail *Rhipidura javanica*	Insectivore	R	LC
		Glossy Swiftlet *Collocalia esculenta*	Insectivore	R	LC
		Pygmy Swiftlet *Collocalia troglodytes*	Insectivore	R	LC
		Asian Koel *Eudynamys scolopaceus*	Frugivore	R/M	LC
		Whiskered Treeswift *Hemiprocne comata*	Insectivore	R	LC
		Savanna Nightjar *Caprimulgus affinis*	Insectivore	R	LC
		Purple Heron *Ardea purpurea*	Piscivore, carnivore	R/M	LC
		Great-billed Heron *Ardea sumatrana*	Piscviore	R	LC
		Rufous Nightheron *Nycticorax caledonicus*	Piscivore	R	LC

		Emerald Dove *Chalcophaps indica*	Granivore, frugivore	R	LC
		Mindanao Bleeding-heart *Gallicolumba criniger*	Granivore, frugivore, insectivore	R	VU
		Zebra Dove *Geopelia striata*	Granivore	R	LC
		White-eared Brown-dove *Phapitreron leucotis*	Frugivore, granivore	R	LC
		Yellow-breasted Fruit-dove *Ptilinopus occipitalis*	Frugivore	R	LC
		Silvery Kingfisher *Alcedo argentata*	Piscivore	R	NT
		Oriental Dollarbird *Eurystomus orientalis*	Insectivore	R/M	LC
		Collared Kingfisher *Halcyon chloris*	Piscivore	R	LC
		White-throated Kingfisher *Halcyon smyrnensis*	Insectivore, piscivore	R	LC
		Blue-throated Bee-eater *Merops viridis*	Insectivore	R/M	LC
		Brush Cuckoo *Cacomantis variolosus*	Insectivore	R	LC
		Lesser Coucal *Centropus bengalensis*	Insectivore	R	LC
		Black-faced Coucal *Centropus melanops*	Insectivore	R	LC
		Philippine Coucal *Centropus viridis*	Insectivore	R	LC

		Brown Cuckoo-Dove *Macropygia phasianella*	Frugivore, granivore	M	LC
		Besra *Accipiter virgatus*	Carnivore	R	LC
		Crested Serpent-eagle *Spilornis cheela*	Carnivore	R	LC
		Philippine Serpent Eagle *Spilornis holospilus*	Carnivore	R	LC
		King Quail *Coturnix chinensis*	Granivore	R	LC
		White-breasted Waterhen *Amaurornis phoenicurus*	Piscivore	R/M	LC
		Barred Rail *Gallirallus torquatus*	Insectivore, piscivore	R	LC
		Purple Swamphen *Porphyrio porphyrio*	Omnivore	R	LC
		Slaty-legged Crake *Rallina eurizonoides*	Piscivore	R	LC
		Spotted Dove *Streptopelia chinensis*	Granivore	R	LC
		Pompadour Green Pigeon *Treron pompadour*	Frugivore	R	LC
		Grey-hooded Sunbird *Aethopyga primigenius*	Nectarivore	R	LC
		Metallic-winged Sunbird *Aethopyga pulcherrima*	Insectivore	R	LC
		Lovely Sunbird *Aethopyga shelleyi*	Insectivore, nectarivore	R	LC
		Naked-faced Spiderhunter *Arachnothera clarae*	Nectarivore	R	LC

		Little Spiderhunter *Arachnothera longirostra*	Nectarivore, insectivore	R	LC
		Olive-backed Sunbird *Nectarinia jugularis*	Nectarivore, frugivore, insectivore	R	LC
		Purple-throated Sunbird *Leptocoma sperata*	Nectarivore	M	LC
		Stripe-sided Rhabdornis *Rhabdornis mystacalis*	Insectivore, frugivore, granivore	R	LC
		Pied Fantail *Rhipidura javanica*	Insectivore	R	LC
		Coleto *Sarcops calvus*	Frugivore, insectivore	R	LC
		Asian Glossy Starling *Aplonis panayensis*	Frugivore	R	LC
		Velvet-fronted Nuthatch *Sitta frontalis*	Insectivore	R	LC
		White-breasted Woodswallow *Artamus leucorhynchus*	Insectivore	R	LC
		Golden-headed Cisticola *Cisticola exilis*	Insectivore	R	LC
		Oriental Magpie-robin *Copsychus saularis*	Insectivore	R	LC
		Mangrove Blue Flycatcher *Cyornis rufigastra*	Insectivore	R	LC
		Turquoise Flycatcher *Eumyias panayensis*	Insectivore	R	LC
		Little Slaty Flycatcher *Ficedula basilanica*	Insectivore	R	VU

		Grey-streaked Flycatcher *Muscicapa griseisticta*	Insectivore	R	LC
		Slender-billed Crow *Corvus enca*	Omivore	R	LC
		Red-keeled Flowerpecker *Dicaeum australe*	Nectarivore, frugivore	R	LC
		Bi-coloured Flowerpecker *Dicaeum bicolor*	Nectarivore	R	LC
		Olive-capped Flowerpecker *Dicaeum nigrilore*	Frugivore, nectarivore	R	LC
		Orange-bellied Flowerpecker *Dicaeum trigonostigma*	Frugivore	R	LC
		Olive-backed Flowerpecker *Prionochilus olivaceus*	Frugivore, nectarivore	R	LC
		Pygmy Flowerpecker *Dicaeum pygmaeum*	Frugivore, insectivore	R	LC
		Black-naped Monarch *Hypothymis azurea*	Insectivore	R	LC
		Philippine Bulbul *Ixos philippinus*	Insectivore, frugivore	R	LC
		Pied Triller *Lalage nigra*	Insectivore, frugivore	R	LC
		Tricoloured Munia *Lonchura malacca*	Granivore	R	LC
		White-bellied Munia *Lonchura leucogastra*	Granivore	R	LC
		Brown-tit Babbler *Macronous striaticeps*	Insectivore	R	LC
		Striated Grassbird	Insectivore	R	LC

		Megalurus palustris			
		Tawny Grassbird *Megalurus timoriensis*	Granivore, insectivore	R	LC
		Philippine Tailorbird *Orthotomus castaneiceps*	Insectivore	R	LC
		Mountain Tailorbird *Orthotomus cuculatus*	Insectivore	R	LC
		Black-headed Tailorbird *Orthotomus nigriceps*	Insectivore	R	LC
		Eastern Crowned Warbler *Phylloscopus coronatus*	Insectivore	M	LC
		Philippine Leaf-Warbler *Phylloscopus olivaceus*	Insectivore	R	LC
		Mountain Leaf-warbler *Phylloscopus trivirgatus*	Insectivore	R	LC
		Yellow-bellied Whistler *Pachycephala philippinensis*	Insectivore	R	LC
		Elegant Tit *Parus elegans*	Insectivore, frugivore, granivore	R	LC
		Eurasian Tree Sparrow *Passer montanus*	Granivore	R	LC
		Grey Wagtail *Motacilla cinerea*	Insectivore	R	LC
		Black-naped Oriole *Oriolus chinensis*	Frugivore	R	LC
		Red-bellied Pitta *Pitta erythrogaster*	Insectivore	R	LC
		Hooded Pitta *Pitta sordida*	Insectivore	R	LC

Bernardo (2017)	Transect	Striated Wren-babbler *Ptilocichla mindanensis*	Insectivore	R	LC
		Yellow-vented Bulbul *Pycnonotus goiavier*	Omnivore	R	LC
		Yellow-wattled Bulbul *Pycnonotus urostictus*	Frugivore	R	LC
		Mountain White-eye *Zosterops montanus*	Omnivore	R	LC
		Pacific Swallow *Hirundo tahitica*	Insectivore	R	LC
		Coppersmith Barbet *Megalaima haemacephala*	Frugivore	R	LC
		Guaiabero *Bolbopsittacus lunulatus*	Frugivore, granivore	R	LC
		Philippine Hanging-parrot *Loriculus philippensis*	Nectarivore	R	LC
		White-bellied Munia *Lonchura leucogastra*	Granivore	R	LC
		Chestnut Munia *Lonchura malacca*	Granivore	M	LC
		Scaly-breasted Munia *Lonchura punctulata*	Granivore	R	LC
		Eurasian Tree Sparrow *Passer montanus*	Granivore	R	LC
		Little Spiderhunter *Arachnothera longirostra*	Nectarivore, insectivore	R	LC
		Olive-backed Sunbird *Nectarinia jugularis*	Nectarivore, frugivore, insectivore	R	LC

		Brown-throated Sunbird *Anthreptes malacensis*	Insectivore	R	LC
		Asian Glossy Starling *Aplonis panayensis*	Frugivore	R	LC
		Brown Shrike *Lanius cristatus*	Insectivore	M	LC
		White-breasted Woodswallow *Artamus leucorhynchus*	Insectivore	R	LC
		Grey Wagtail *Motacilla cinerea*	Insectivore	R	LC
		Black-Naped Monarch *Hypothymis azurea*	Insectivore	R	LC
		Pied Fantail *Rhipidura javanica*	Insectivore	R	LC
		Grey-streaked Flycatcher *Muscicapa griseisticta*	Insectivore	R	LC
		White-Vented Shama *Copsychus niger*	Insectivore	R	LC
		Rufous-tailed Tailorbird *Orthotomus sericeus*	Insectivore	R	LC
		Striated Grassbird *Megalurus palustris*	Insectivore	R	LC
		Little Egret *Egretta garzetta*	Piscivore	M	LC
		Cattle Egret *Bubulcus ibis*	Piscivore	M	LC
		Intermediate Egret *Egretta intermedia*	Piscivore	R	LC
		Crested Serpent-eagle *Spilornis cheela*	Carnivore	R	LC

		King Quail *Coturnix chinensis*	Granivore	R	LC
		Barred Buttonquail *Turnix suscitator*	Granivore	R	LC
		White-Breasted Waterhen *Amaurornis phoenicurus*	Piscivore	R/M	LC
		Spotted Dove *Streptopelia chinensis*	Granivore	R	LC
		Zebra Dove *Geopelia striata*	Granivore	R	LC
		Emerald dove *Chalcophaps indica*	Granivore, frugivore	R	LC
		Lesser Coucal *Centropus bengalensis*	Insectivore	R	LC
		Glossy Swiftlet *Collocalia esculenta*	Insectivore	R	LC
		Brown-Backed Needletail *Hirundapus giganteus*	Insectivore	R	LC
		Oriental Dwarf-Kingfisher *Ceryx erithacus rufidorsa*	Insectivore	R	LC
		White-Collared Kingfisher *Halcyon chloris*	Piscivore	R	LC
		Barn Swallow *Hirundo rustica*	Insectivore	M	LC
		Pied Triller *Lalage nigra*	Insectivore, frugivore	R	LC
		Black-headed Bulbul *Pycnonotus atriceps*	Frugivore	R	LC
		Olive-winged Bulbul *Pycnonotus plumosus*	Frugivore, insectivore	R	LC

		Ashy Drongo *Dicrurus leucophaeus*	Insectivore, nectarivore	R	LC
		Slender-billed Crow *Corvus enca*	Omivore	R	LC
		Striped Tit-Babbler *Macronous gularis*	Insectivore	R	LC
Borneo					
Gervais et al. (2012)	Transect	Little Egret *Egretta garzetta*	Piscivore	M	LC
		White-breasted Waterhen *Amaurornis phoenicurus*	Piscivore	R/M	LC
		Spotted Dove *Streptopelia chinensis*	Granivore	R	LC
		Indian Cuckoo *Cuculus micropterus*	Insectivore	R	LC
		Greater Coucal *Centropus sinensis*	Carnivore	R	LC
		Pacific Swallow *Hirundo tahitica*	Insectivore	R	LC
		Yellow-vented Bulbul *Pycnonotus goiavier*	Omnivore	R	LC
		Slender-billed Crow *Corvus enca*	Omivore	R	LC
		Bold-striped Tit-Babbler *Macronous bornensis*	Insectivore, frugivore	R	LC
		Oriental Magpie-Robin *Copsychus saularis*	Insectivore	R	LC

		Rufous-tailed Tailorbird *Orthotomus sericeus*	Insectivore	R	LC
		Yellow-bellied Prinia *Prinia flaviventris*	Insectivore	R	LC
		Pied Fantail *Rhipidura javanica*	Insectivore	R	LC
		Crimson Sunbird *Aethopyga siparaja*	Insectivore, nectarivore	R	LC
		Eurasian Tree Sparrow *Passer montanus*	Granivore	R	LC
		Dusky Munia *Lonchura fuscans*	Granivore	R	LC
		Black-headed Munia *Lonchura malacca*	Granivore	R	LC
		Spotted Dove *Streptopelia chinensis*	Granivore	R	LC
Koh (2008)	Transect	Bronzed Drongo *Dicrurus aeneus*	Insectivore	R	LC
		Asian Glossy Starling *Aplonis panayensis*	Frugivore	R	LC
		Plain Sunbird *Anthreptes simplex*	Nectarivore, insectivore	R	LC
		Copper-throated Sunbird *Nectarinia calcostetha*	Nectarivore, insectivore	R	LC
		White-rumped Shama *Copsychus malabaricus*	Insectivore	R	LC
		Slender-billed Crow *Corvus enca*	Omivore	R	LC

		Common Sandpiper *Tringa hypoleucos*	Insectivore, piscivore	R	LC
		Black-nest Swiftlet *Collocalia maxima*	Insectivore	R	LC
		Oriental Dollarbird *Eurystomus orientalis*	Insectivore	R/M	LC
		Zebra Dove *Geopelia striata*	Granivore	R	LC
		Spotted Dove *Streptopelia chinensis*	Granivore	R	LC
		White-breasted Waterhen *Amaurornis phoenicurus*	Piscivore	R/M	LC
		Crimson Sunbird *Aethopyga siparaja*	Insectivore, nectarivore	R	LC
		Common Kingfisher *Alcedo atthis*	Piscivore	R	LC
		Collared Kingfisher *Halcyon chloris*	Piscivore	R	LC
		Oriental Darter *Anhinga melanogaster*	Piscivore	R	NT
		Striated Heron *Butorides striatus*	Piscivore	R/M	LC
		White-breasted Woodswallow *Artamus leucorhynchus*	Insectivore	R	LC
		Emerald Dove *Chalcophaps indica*	Granivore, frugivore	R	LC
		Plaintive Cuckoo *Cacomantis merulinus*	Insectivore	R	LC
		Rusty-breasted Cuckoo *Cacomantis sepulcralis*	Insectivore	R	LC

		Greater Coucal *Centropus sinensis*	Carnivore	R	LC
		White-bellied Munia *Lonchura leucogastra*	Granivore	R	LC
		Black-headed Munia *Lonchura malacca*	Granivore	R	LC
		Barn Swallow *Hirundo rustica*	Insectivore	M	LC
		Sand Martin *Riparia riparia*	Piscivore	R	LC
		Common Iora *Aegithina tiphia*	Insectivore	R	LC
		Olive-backed Sunbird *Nectarinia jugularis*	Nectarivore, frugivore, insectivore	R	LC
		Red-eyed Bulbul *Pycnonotus brunneus*	Frugivore	R	LC
		Yellow-vented Bulbul *Pycnonotus goiavier*	Omnivore	R	LC
		Pied Fantail *Rhipidura javanica*	Insectivore	R	LC
		Ashy Tailorbird *Orthotomus sepium*	Insectivore	R	LC
		Rufous-tailed Tailorbird *Orthotomus sericeus*	Insectivore	R	LC
		Yellow-bellied Prinia *Prinia flaviventris*	Insectivore	R	LC
		Striped Tit-babbler *Macronous gularis*	Insectivore	R	LC

		Oriental Magpie Robin *Copsychus saularis*	Insectivore	R	LC
		Rufous Woodpecker *Celeus brachyurus*	Insectivore	R	LC
Sheldon, Styring & Hosner (2010)	20 minutes point count at 50m intervals along 1km straight transect	King Quail *Coturnix chinensis*	Granivore	R	LC
		Crested Partridge *Rollulus rouloul*	Granivore	R	NT
		Spotted Dove *Streptopelia chinensis*	Granivore	R	LC
		Emerald Dove *Chalcophaps indica*	Granivore, frugivore	R	LC
		Plaintive Cuckoo *Cacomantis merulinus*	Insectivore	R	LC
		Greater Coucal *Centropus sinensis*	Carnivore	R	LC
		Lesser Coucal *Centropus bengalensis*	Insectivore	R	LC
		Blue-eared Kingfisher *Alcedo meninting*	Piscivore	R	LC
		Collared Kingfisher *Halcyon chloris*	Piscivore	R	LC
		Rufous Piculet *Sasia abnormis*	Insectivore	R	LC
		Yellow-vented Bulbul *Pycnonotus goiavier*	Omnivore	R	LC
		Olive-winged Bulbul *Pycnonotus plumosus*	Frugivore, insectivore	R	LC

		Yellow-bellied Prinia *Prinia flaviventris*	Insectivore	R	LC
		Ashy Tailorbird *Orthotomus sepium*	Insectivore	R	LC
		Rufous-tailed Tailorbird *Orthotomus sericeus*	Insectivore	R	LC
		Oriental Magpie-Robin *Copsychus saularis*	Insectivore	R	LC
		Pied Fantail *Rhipidura javanica*	Insectivore	R	LC
		White-chested Babbler *Trichastoma rostratum*	Insectivore	R	NT
		Black-capped Babbler *Pellorneum capistratum*	Insectivore	R	LC
		Striped Tit-Babbler *Macronous gularis*	Insectivore	R	LC
		Crimson Sunbird *Aethopyga siparaja*	Insectivore, nectarivore	R	LC
		Little Spiderhunter *Arachnothera longirostra*	Nectarivore, insectivore	R	LC
		Yellow-rumped Flowerpecker *Prionochilus xanthopygius*	Nectarivore	R	LC
		Orange-bellied Flowerpecker *Dicaeum trigonostigma*	Frugivore	R	LC
		Slender-billed Crow *Corvus enca*	Omivore	R	LC
Edwards et al. (2013)	15 minutes point count at 250m intervals along transect	Blue-throated Bee-eater *Merops viridis*	Insectivore	R/M	LC

		Little Egret *Egretta garzetta*	Piscivore	M	LC
		White-breasted Waterhen *Amaurornis phoenicurus*	Piscivore	R/M	LC
		Olive-backed Sunbird *Nectarinia jugularis*	Nectarivore, frugivore, insectivore	R	LC
		Collared Kingfisher *Halcyon chloris*	Piscivore	R	LC
		Spotted Dove *Streptopelia chinensis*	Granivore	R	LC
		Asian Glossy Starling *Aplonis panayensis*	Frugivore	R	LC
		Mangrove Blue Flycatcher *Cyornis rufigastra*	Insectivore	R	LC
		Oriental Pied Hornbill *Anthracoceros albirostris*	Frugivore	R	LC
		Rufous-bellied Eagle *Lophotriorchis kienerii*	Carnivore	R	NT
		Black Eagle *Ictinaetus malaiensis*	Carnivore	R	LC
Amit et al. (2014)	Mist-netting & transect	Little Spiderhunter *Arachnothera longirostra*	Nectarivore, insectivore	R	LC
		Brown-throated Sunbird *Anthreptes malacensis*	Insectivore	R	LC
		Chestnut-winged Babbler *Stachyris erythroptera*	Insectivore	R	LC
		Striped tit-babbler *Macronous gularis*	Insectivore	R	LC

		Yellow-vented Bulbul *Pycnonotus goiavier*	Omnivore	R	LC
		Red-eyed Bulbul *Pycnonotus brunneus*	Frugivore	R	LC
		Spectacled Bulbul *Pycnonotus erythropthalmos*	Frugivore, insectivore	R	LC
		Black-and-White Bulbul *Pycnonotus melanoleucos*	Frugivore	R	NT
		Rufous-backed Kingfisher *Ceyx rufidorsa*	Piscivore	R	LC
		Stork-billed Kingfisher *Halcyon capensis*	Piscivore	R	LC
		Banded Kingfisher *Lacedo pulchella*	Piscivore, insectivore	R	LC
		Pied Fantail *Rhipidura javanica*	Insectivore	R	LC
		Reddish Scops-owl *Otus rufescens*	Insectivore	R	NT
		Brown Hawk-owl *Ninox scutulata*	Insectivore, carnivore	R/M	LC
		Crested Serpent-eagle *Spilornis cheela*	Carnivore	R	LC
		Rufous Piculet *Sasia abnormis*	Insectivore	R	LC
		Ashy Tailorbird *Orthotomus sepium*	Insectivore	R	LC
		Rufous-tailed Tailorbird *Orthotomus sericeus*	Insectivore	R	LC
		Yellow-bellied Prinia *Prinia flaviventris*	Insectivore	R	LC

		Yellow-bellied Warbler *Abroscopus superciliari*	Insectivore	R	LC
		Rusty-rumped Warbler *Locustella certhiola*	Insectivore	R	LC
		Plaintive Cuckoo *Cacomantis merulinus*	Insectivore	R	LC
		Banded Bay Cuckoo *Cacomantis sonneratii*	Insectivore	R	LC
		Greater Coucal *Centropus sinensis*	Carnivore	R	LC
		Asian Glossy Starling *Aplonis panayensis*	Frugivore	R	LC
		Barn Swallow *Hirundo rustica*	Insectivore	M	LC
		Pacific Swallow *Hirundo tahitica*	Insectivore	R	LC
		Dusky Munia *Lonchura fuscans*	Granivore	R	LC
		Chestnut Munia *Lonchura malacca*	Granivore	M	LC
		Oriental Magpie Robin *Copsychus saularis*	Insectivore	R	LC
		King Quail *Coturnix chinensis*	Granivore	R	LC
		White-breasted Waterhen *Amaurornis phoenicurus*	Piscivore	R/M	LC
		Spotted Dove *Streptopelia chinensis*	Granivore	R	LC
		Long-tailed Parakeet	Frugivore	R	VU

		Psittacula longicauda			
		Little Egret *Egretta garzetta*	Piscivore	M	LC
		Intermediate Egret *Egretta intermedia*	Piscivore	R	LC
		Cattle Egret *Bubulcus ibis*	Piscivore	M	LC
		Common Sandpiper *Tringa hypoleucos*	Insectivore, piscivore	R	LC
		Large-tailed Nightjar *Caprimulgus macrurus*	Insectivore	R	LC
		Mossy-nest Swiftlet *Aerodramus salanganus*	Insectivore	R	LC
		Common Iora *Aegithina tiphia*	Insectivore	R	LC
		Greater Racquet-tailed Drongo *Dicrurus paradiseus*	Insectivore	R	LC
Mitchell et al. (2018)	15 minutes point counts at 180-220m intervals along transect	Zebra Dove *Geopelia striata*	Granivore	R	LC
		Olive-backed Sunbird *Nectarinia jugularis*	Nectarivore, frugivore, insectivore	R	LC
		Dusky Munia *Lonchura fuscans*	Granivore	R	LC
		Little Egret *Egretta garzetta*	Piscivore	M	LC
		Common Sandpiper *Tringa hypoleucos*	Insectivore, piscivore	R	LC

		Orange-backed Woodpecker *Chrysocolaptes validus*	Insectivore	R	LC
		Lesser Coucal *Centropus bengalensis*	Insectivore	R	LC
Mulyani et al. (2018)	Mist-netting	Besra *Accipiter virgatus*	Carnivore	R	LC
		White-breasted Waterhen *Amaurornis phoenicurus*	Piscivore	R/M	LC
		Stork-billed Kingfisher *Halcyon capensis*	Piscivore	R	LC
		Emerald dove *Chalcophaps indica*	Granivore, frugivore	R	LC
		Plaintive Cuckoo *Cacomantis merulinus*	Insectivore	R	LC
		Blue-eared Kingfisher *Alcedo meninting*	Piscivore	R	LC
		Puff-backed Bulbul *Pycnonotus eutilotus*	Frugivore, insectivore	R	NT
		Olive-winged Bulbul *Pycnonotus plumosus*	Frugivore, insectivore	R	LC
		Yellow-vented Bulbul *Pycnonotus goiavier*	Omnivore	R	LC
		Cream-vented Bulbul *Pycnonotus simplex*	Frugivore, insectivore	R	LC
		Red-eyed Bulbul *Pycnonotus brunneus*	Frugivore	R	LC
		Long-Tailed Shrike *Lanius schach*	Insectivore, carnivore	R	LC

		White-rumped Shama *Copsychus malabaricus*	Insectivore	R	LC
		Fluffy-backed Tit-Babbler *Macronous ptilosus*	Insectivore	R	NT
		Striped Tit-Babbler *Macronous gularis*	Insectivore	R	LC
		White-chested Babbler *Trichastoma rostratum*	Insectivore	R	NT
		Rufous-tailed Tailorbird *Orthotomus sericeus*	Insectivore	R	LC
		Ashy Tailorbird *Orthotomus sepium*	Insectivore	R	LC
		Pied Fantail *Rhipidura javanica*	Insectivore	R	LC
		Crimson Sunbird *Aethopyga siparaja*	Insectivore, nectarivore	R	LC
		Brown-throated Sunbird *Anthreptes malacensis*	Insectivore	R	LC
		Ruby-cheeked Sunbird *Anthreptes singalensis*	Insectivore, frugivore	R	LC
		Little Spiderhunter *Arachnothera longirostra*	Nectarivore, insectivore	R	LC
		Dusky Munia *Lonchura fuscans*	Granivore	R	LC
Santosa, Sugiharti & Erniwati (2018)	Transect	Lesser Coucal *Centropus bengalensis*	Insectivore	R	LC
		Pied Fantail *Rhipidura javanica*	Insectivore	R	LC

Yudea & Santosa (2019)	Transect	Olive-winged Bulbul *Pycnonotus plumosus*	Frugivore, insectivore	R	LC
		Yellow-vented bulbul *Pycnonotus goiavier*	Omnivore	R	LC
		Spotted dove *Streptopelia chinensis*	Granivore	R	LC
		Cinnamon Bittern *Dupetor flavicollis*	Piscivore	R	LC
		Long-Tailed Shrike *Lanius schach*	Insectivore, carnivore	R	LC
		Long-tailed parakeet *Psittacula longicauda*	Frugivore	R	VU
		Lesser Coucal *Centropus bengalensis*	Insectivore	R	LC
		Greater Coucal *Centropus sinensis*	Carnivore	R	LC
		White-throated Kingfisher *Halcyon smyrnensis*	Insectivore, piscivore	R	LC
		Collared Kingfisher *Halcyon chloris*	Piscivore	R	LC
		Ashy Tailorbird *Orthotomus sepium*	Insectivore	R	LC
		Grey-headed Fish-Eagle *Ichthyophaga ichthyaetus*	Carnivore, piscivore	R	NT
		Slender-billed Crow *Corvus enca*	Omivore	R	LC
		Black-winged Flycatcher-shrike *Hemipus hirundinaceus*	Insectivore	R	LC

		Oriental Magpie Robin *Copsychus saularis*	Insectivore	R	LC
		Black Hornbill *Anthracoceros malayanus*	Frugivore, insectivore	R	VU
		Oriental Pied Hornbill *Anthracoceros albirostris*	Frugivore	R	LC
		White-breasted Waterhen *Amaurornis phoenicurus*	Piscivore	R/M	LC
		Crested Myna *Acridotheres cristatellus*	Frugivore	R	LC
		Pied Fantail *Rhipidura javanica*	Insectivore	R	LC
		Chinese Egret *Egretta eulophotes*	Piscivore	R	VU
		Cattle Egret *Bubulcus ibis*	Piscivore	M	LC
		Pacific Swallow *Hirundo tahitica*	Insectivore	R	LC
		Yellow-vented Bulbul *Pycnonotus goiavier*	Omnivore	R	LC
		Red-eyed Bulbul *Pycnonotus brunneus*	Frugivore	R	LC
		Banded Woodpecker *Picus miniaceus*	Insectivore	R	LC
		Yellow-bellied Prinia *Prinia flaviventris*	Insectivore	R	LC
		Green Imperial Pigeon *Ducula aenea*	Frugivore	R	LC
		Pink-necked Green-Pigeon	Frugivore	R	LC

		Treron vernans			
		Blue-eared Kingfisher *Alcedo meninting*	Piscivore	R	LC
		Greater racquet-tailed drongo *Dicrurus paradiseus*	Insectivore	R	LC
		Spotted Dove *Streptopelia chinensis*	Granivore	R	LC
		Oriental Dollarbird *Eurystomus orientalis*	Insectivore	R/M	LC
		Hill myna *Gracula religiosa*	Frugivore	R	LC
		Glossy Swiftlet *Collocalia esculenta*	Insectivore	R	LC
		Black Bittern *Ixobrychus flavicollis*	Piscivore, carnivore, insectivore	R	LC
Mohd-Azlan et al. (2019)	Mist-netting	Blue-eared Kingfisher *Alcedo meninting*	Piscivore	R	LC
		Oriental Dwarf Kingfisher *Ceyx erithaca*	Insectivore	R	LC
		Black-nest Swiftlet *Collocalia maxima*	Insectivore	R	LC
		Glossy Swiftlet *Collocalia esculenta*	Insectivore	R	LC
		Yellow-bellied Prinia *Prinia flaviventris*	Insectivore	R	LC
		Common Emerald Dove *Chalcophaps indica*	Granivore, frugivore	R	LC

		Orange-bellied Flowerpecker *Dicaeum trigonostigma*	Frugivore	R	LC
		Yellow-rumped Flowerpecker *Prionochilus xanthopygius*	Nectarivore	R	LC
		Black-headed Munia *Lonchura malacca*	Granivore	R	LC
		Dusky Munia *Lonchura fuscans*	Granivore	R	LC
		Blue-throated Bee-eater *Merops viridis*	Insectivore	R/M	LC
		Brown-throated Sunbird *Anthreptes malacensis*	Insectivore	R	LC
		Crimson Sunbird *Aethopyga siparaja*	Insectivore, nectarivore	R	LC
		Little Spiderhunter *Arachnothera longirostra*	Nectarivore, insectivore	R	LC
		Plain Sunbird *Anthreptes simplex*	Nectarivore, insectivore	R	LC
		Short-tailed Babbler *Trichastoma malaccense*	Insectivore	R	NT
		Olive-winged Bulbul *Pycnonotus plumosus*	Frugivore, insectivore	R	LC
		Spectacled Bulbul *Pycnonotus erythropthalmos*	Frugivore, insectivore	R	LC
		Yellow-vented Bulbul *Pycnonotus goiavier*	Omnivore	R	LC
		White-breasted Waterhen *Amaurornis phoenicurus*	Piscivore	R/M	LC
		Pied Fantail *Rhipidura javanica*	Insectivore	R	LC

		Sunda Scops-Owl *Otus lettia*	Insectivore, carnivore	R	LC
		Reddish Scops-owl *Otus rufescens*	Insectivore	R	NT
		Ashy Tailorbird *Orthotomus sepium*	Insectivore	R	LC
		Rufous-tailed Tailorbird *Orthotomus sericeus*	Insectivore	R	LC
		Black-capped Babbler *Pellorneum capistratum*	Insectivore	R	LC
		Bold-striped Tit-Babbler *Macronous bornensis*	Insectivore, frugivore	R	LC
		Oriental Magpie Robin *Copsychus saularis*	Insectivore	R	LC
		White-rumped Shama *Copsychus malabaricus*	Insectivore	R	LC

CR: Critically Endangered, NT: Near Threatened, LC: Least concern, VU: Vulnerable (according to IUCN species category), R: resident, M: migrant

Appendix C: No. of individuals in surveyed sites using point-count method

Species	Bangi	Banting	Keratong	Rembau	Serdang	Feeding Guild	Status of Residency	IUCN Status
Common Tailorbird	23	4	11	213	12	Insectivore	R	LC
Blue-throated Bee-eater	0	2	0	5	0	Insectivore	R/M	LC
Edible-nest Swiftlet	0	0	0	117	0	Insectivore	R	LC
Oriental Magpie-robin	15	7	33	209	3	Insectivore	R	LC
Dollarbird	0	0	0	9	0	Insectivore	R/M	LC
Asian Brown Flycatcher	1	1	0	0	0	Insectivore	M	LC
Blue-winged Pitta	0	0	0	2	0	Insectivore	R	LC
Red-wattled Lapwing	0	0	0	10	0	Insectivore	R	LC
Pied Fantail	1	0	0	15	1	Insectivore	R	LC
Rufescent Prinia	5	3	0	3	6	Insectivore	R	LC
Racket-tailed Drongo	0	0	0	6	0	Insectivore	R	LC
Pacific Swallow	0	0	0	13	0	Insectivore	R	LC
Rufous Woodpecker	0	0	1	5	0	Insectivore	R	LC
Raffle's Malkoha	0	0	0	1	0	Insectivore	R	LC

Common Flameback	0	0	0	3	0	Insectivore	R	LC
Black-thighed Falconet	1	0	0	0	0	Carnivore	R	LC
Rufous-tailed Tailorbird	0	0	0	10	0	Insectivore	R	LC
Yellow-bellied Prinia	0	0	0	7	0	Insectivore	R	LC
Dark-necked Tailorbird	0	0	0	2	0	Insectivore	R	LC
Barn Swallow	0	0	0	1	0	Insectivore	M	LC
Black-capped Babbler	0	0	0	1	0	Insectivore	R	LC
House Swift	0	0	0	1	0	Insectivore	R	LC
Banded Bay Cuckoo	0	0	0	2	0	Insectivore	R	LC
Large-tailed Nightjar	0	0	0	1	0	Insectivore	R	LC
Pin-striped Tit-babbler	0	0	0	1	0	Insectivore	R	LC
Hooded Pitta	0	0	0	1	0	Insectivore	R	LC
White-rumped Shama	0	0	0	1	0	Insectivore	R	LC
Ashy Tailorbird	9	0	2	9	1	Insectivore	R	LC
Brown Shrike	0	0	0	7	0	Insectivore	M	LC
White-breasted Waterhen	1	0	6	18	0	Piscivore	R/M	LC

Common Iora	1	0	0	30	0	Insectivore	R	LC
Paddyfield Pipit	0	0	0	2	0	Insectivore	R	LC
Crimson-winged Woodpecker	0	0	0	2	0	Insectivore	R	LC
Oriental Honey Buzzard	1	0	0	1	0	Carnivore	R	LC
Plain-throated Sunbird	0	0	0	7	0	Nectarivore	R	LC
Olive-backed Sunbird	0	0	0	10	0	Nectarivore	R	LC
White-throated Kingfisher	4	4	18	76	0	Piscivore	R	LC
Yellow-vented Bulbul	18	5	8	211	5	Omnivore	R	LC
Red Junglefowl	8	10	6	25	2	Omnivore	R	LC
Javan Myna	8	12	0	320	0	Omnivore	R	VU
Common Myna	0	0	1	34	0	Omnivore	R	LC
Stripe-throated Bulbul	1	0	0	17	0	Frugivore	R	LC
Cream-vented Bulbul	0	0	1	0	0	Frugivore	R	LC
Large-billed Crow	0	0	0	4	0	Omnivore	R	LC
House Crow	0	4	1	5	0	Omnivore	R	LC
Olive-winged Bulbul	0	0	0	7	0	Frugivore	R	LC

Crested Serpent-eagle	5	1	7	7	0	Carnivore	R	LC
Changeable Hawk-eagle	3	0	0	5	0	Carnivore	R	LC
Greater Coucal	2	2	1	2	1	Carnivore	R	LC
Spotted Dove	1	0	6	43	0	Granivore	R	LC
Zebra Dove	3	9	9	48	0	Granivore	R	LC
Emerald Dove	0	0	0	2	0	Granivore	R	LC
Barred Butonquail	0	0	0	1	0	Granivore	R	LC
Rock Pigeon	0	0	0	10	0	Granivore	R	LC
Scaly-breasted Munia	0	0	0	3	0	Granivore	R	LC
Black-naped Oriole	3	0	4	47	0	Frugivore	R	LC
Golden-whiskered Barbet	0	0	0	1	0	Frugivore	R	LC
Pink-necked Green Pigeon	0	1	0	28	0	Frugivore	R	LC
Asian Glossy Starling	22	0	0	111	1	Frugivore	R	LC
Blue-crowned Hanging-parrot	0	0	0	6	0	Frugivore	R	LC
Lineated Barbet	1	0	0	0	0	Frugivore	R	LC
Red-eyed Bulbul	0	0	0	3	0	Frugivore	R	LC

Scarlet-backed Flowerpecker	0	0	0	17	0	Frugivore	R	LC
Asian Koel	0	4	0	7	4	Frugivore	R/M	LC
Long-tailed Parakeet	0	0	0	1	0	Frugivore	R	VU
Spectacled Spiderhunter	0	0	0	3	0	Insectivore	R	LC
Grey-breasted Spiderhunter	0	0	0	4	0	Insectivore	R	LC
Lesser Whistling-duck	0	0	0	8	0	Omnivore	R	LC
Collared Kingfisher	0	0	0	6	2	Piscivore	R	LC
Blue-eared Kingfisher	0	0	0	1	0	Piscivore	R	LC
Brown-throated Sunbird	0	2	4	0	0	Insectivore	R	LC
Purple Heron	0	0	1	0	0	Piscivore	R/M	LC
Hill Myna	2	0	0	0	0	Frugivore	R	LC

LC: Least Concern, VU: Vulnerable (according to IUCN species category), R: resident, M: migrant

Appendix D: Opportunistic survey bird checklists for Bangi and Serdang based on indicator species in Peninsular Malaysia

	Bangi	**Serdang**
Spotted Dove	✓	
Common Myna	✓	
Common Tailorbird	✓	✓
Javan Myna		✓
Zebra Dove		
White-breasted Waterhen		
Asian Glossy Starling	✓	✓
Black-naped Oriole	✓	
Crested Serpent-eagle		
White-throated Kingfisher	✓	✓
Yellow-vented Bulbul	✓	✓
Oriental Magpie-robin	✓	✓
Collared Kingfisher		
Common Flameback		
Greater Coucal	✓	
Little Egret		
Purple Heron		
Red Junglefowl	✓	✓
Asian Koel		✓
Pied Fantail		✓
Total species	10	9
%	50	45
Additional species	Rufescent Prinia Ashy Tailorbird Lineated Barbet	Rufous Woodpecker Ashy Tailorbird Rufescent Prinia Black-thighed Falconet Asian Brown Flycatcher Lineated Barbet Yellow-bellied Prinia Pink-necked Green Pigeon Scarlet-backed Flowerpecker Pied Triller Emerald Dove

Tick (✓): presence of bird species in the surveyed area

Appendix E: Collection of indicator species of Peninsular Malaysia

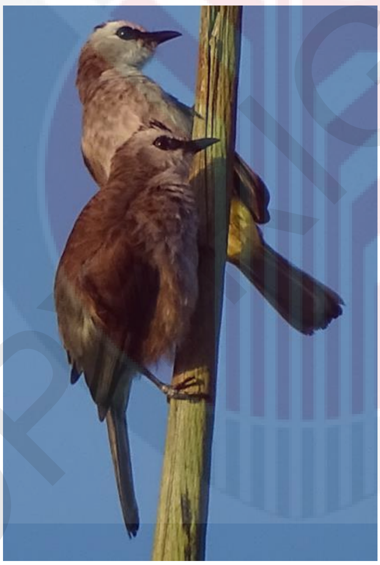
Picture	Species
	Spotted Dove
 (Photo credit: Mohd Syafiq Yahya)	Common Myna

 (Photo credit: Mohd Syafiq Yahya)	Common Tailorbird
	Javan Myna

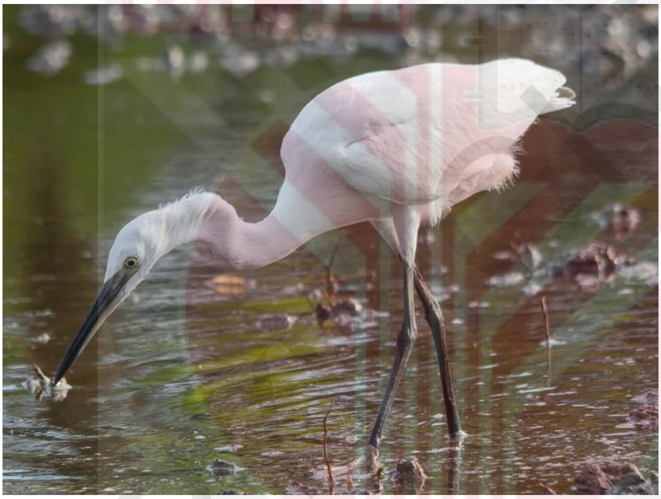
 (Photo credit: Mohd Syafiq Yahya)	Zebra Dove
 (Photo credit: Mohd Syafiq Yahya)	White-breasted Waterhen

	Asian Glossy Starling
	Black-naped Oriole

	Crested-serpent Eagle
	White-throated Kingfisher

 (Photo credit: Mohd Syafiq Yahya)	Oriental Magpie-robin
	Yellow-vented Bulbul

 (Photo credit: Mohd Syafiq Yahya)	Collared Kingfisher
 (Photo credit: Mohd Syafiq Yahya)	Common Flameback

 (Photo credit: Mohd Syafiq Yahya)	Greater Coucal
 (Photo credit: Mohd Syafiq Yahya)	Little Egret

 (Photo credit: Mohd Syafiq Yahya)	Purple Heron
 (Photo credit: Mohd Syafiq Yahya)	Red Junglefowl

 (Photo credit: Mohd Syafiq Yahya)	Asian Koel
 (Photo credit: Mohd Syafiq Yahya)	Pied Fantail

BIODATA OF STUDENT

Nursyamin Hanis binti Zulkifli was born on the 6th of June 1994 in Penang. She started her early education at Sekolah Kebangsaan Bukit Gelugor, Penang. She then continued her secondary education at Sekolah Menengah Kebangsaan Agama (Perempuan) Almashoor, Penang. After Sijil Pelajaran Malaysia, she pursued Foundation in Life Science and then attended bachelor's degree in Animal Resource Science and Management both in Universiti Malaysia Sarawak, Sarawak. Before continuing her master's degree, she has worked as a trail ranger at The Habitat Penang Hill, Penang and as a research assistant with Southeast Asia Rainforest Research Partnership in Tawau, Sabah.

PUBLICATION

Nursyamin, Z., Yahya, M. S., Atikah, S. N., Tohiran, K. A., Norhisham, A. R., Othman, N. W., Lechner, A. M., Azhar, B. (2023). Identifying indicator bird species for sustainable oil palm plantation certification. *Journal of Cleaner Production, 415*, Article e137852.