BIRD COMMUNITY STRUCTURE AND DIVERSITY IN PENINSULAR MALAYSIA

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BIRD COMMUNITY STRUCTURE AND DIVERSITY IN PENINSULAR MALAYSIA

by

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DEDICATION

My humble effort I dedicate

To

Loving parents and grandparents, whose

Utmost efforts and prayers are always with me.

To

Respected teachers, whose

Kind guidance and encouragement helped me to reach at this stage.

To

My husband and little son, whose

Became my backbone throughout this journey.

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LIST OF ABBREVIATIONS

ACE	Abundance-based coverage estimator
AU	Approximately unbiased
AvTD	average taxonomic distinctness
BP	Bootstrap probability
BPO	Borneo Post Online
Chao1	Abundance-based estimator Chao1
Chao2	Incidence-based estimator Chao2
CR	Critically endangered
DOS	Department of Statistics, Malaysia
IADA	Integrated Agriculture Development Area
IADA BLS	Barat Laut Selangor Integrated Agriculture Development Area
IADA KETARA	North Terengganu Integrated Agriculture Development
IADA KSM	Kerian Integrated Agriculture Development Area
ICE	Incidence-based coverage estimator
IUCN	International Union for Conservation of Nature
Jack1	Jackknife1
Jack2	Jackknife2
KADA	Kemubu Agricultural Development Authority
LC	Least Concern
MADA	Muda Agricultural Development Authority
MMMean	Michaelis-Menten model based estimator
MMMRun	Michalis-Menten runs
NE	Northeastern

nMDS	Nonmetric multidimensional scaling
NT	Near-threatened
NW	Northwestern
PAST	Paleontological Statistics
SW	Southwestern
UPMGA	Unweighted Pair-Group Mean Arithmetic
VarTD	Variation in Taxonomic Distinctness
VU	Vulnerable

LIST OF SYMBOLS

Δ^+	Average taxonomic distinctness
Δ**s**	Taxonomic similarity
$\boldsymbol{\Lambda}^+$	Variation in taxonomic distinctness
A	Alpha diversity
B	Beta diversity
$\boldsymbol{\beta}_W$	Whittaker's β-diversity
$\boldsymbol{\gamma}$	Gamma diversity

STUKTUR KOMUNITI DAN KEPELBAGAIAN BURUNG DI SEMENANJUNG MALAYSIA

ABSTRAK

Semenanjung Malaysia mempunyai kepelbagaian flora dan fauna yang tinggi. Kebanyakannya masih belum didokumentasikan. Avifauna merupakan satu kumpulan penting yang kurang mendapat perhatian, secara ekologi di negara ini. Pelbagai pendekatan pengukuran kepelbagaian ditunjukkan di dalam tesis ini bertujuan menilai kepelbagaian burung di habitat semulajadi dan bukan semulajadi. Objektif kajian ini adalah untuk menentukan komposisi dan kepelbagaian terkini spesies burung, menganalisa β-diversiti burung, menyiasat corak kelangkaan dikalangan burung di habitat semulajadi, dan mengkaji sumbangan sawah padi terhadap kepelbagaian burung di Semenanjung Malaysia dengan menggunakan pelbagai kaedah pengukuran kepelbagaian. Data ada/tiada diperoleh daripada sumber primer (2002-2013) dan sekunder (1992-2015) yang telah direkodkan dari 53 kawasan habitat semulajadi. Data primer dan sekunder burung juga telah dikumpul sejak tahun 2013-2014 daripada 83 kawasan sawah padi di sembilan buah negeri, Semenanjung Malaysia. Kaedah *point count* dan pemasangan jaring kabut (*mist-netting*) telah digunakan untuk bancian burung. Keluk pengumpulan spesies telah diplot untuk menerangkan komposisi spesies burung. Tujuh penganggar spesies telah diuji untuk menganggarkan bilangan spesies burung dan menilai prestasi penganggar. β-diversiti telah dihuraikan melalui pengiraan variasi, pulangan perolehan (*turnover*), dan kesamaan taksonomi. Corak kelangkaan dikalangan burung hutan telah ditentukan dengan menggunakan tujuh bentuk kelangkaan Rabinowitz. Manakala sumbangan sawah padi terhadap jumlah keseluruhan bilangan spesies burung di Semenanjung Malaysia telah dianalisa menggunakan pengukuran

keberbezaan taksonomik (*taxonomic distinctness measures*). Empat ratus tiga puluh lapan spesies burung telah direkodkan dari 53 kawasan tapak kajian. MMMeans telah menganggarkan 482 spesies burung untuk habitat semulajadi, Semenanjung Malaysia. Analisis β-diversiti menunjukkan kepelbagaian burung adalah berkadar negatif dengan jarak tetapi berkadar positif dengan ketinggian manakala keberbezaan taksonomik mencadangkan dengan berpandukan kepada kehadiran burung daripada order Passeriformes, bahagian barat menunjukkan kepelbagaian beta yang tinggi dengan skor 0.797. Dari segi kelangkaan pula, 46 burung residen telah dikategorikan sebagai spesies burung yang paling langka dengan saiz populasi yang jarang, habitat spesifikasi yang terhad, dan julat taburan yang terhad. Keputusan daripada analisis *functional diversity* menunjukkan kelangkaan dalam burung mudah berlaku apabila spesies tersebut dikategorikan sebagai '*isospecies*', spesies bawah kanopi, pemakan buah, dan residen biasa di habitat semulajadi tanah tinggi. Di lanskap pertanian tradisional kita, sawah padi mempunyai sumbangan yang signifikan terhadap kepelbagaian burung di Semenanjung Malaysia kerana terdapat banyak burung air di kawasan ini. Keputusan yang didapati akan meningkatkan pemahaman terhadap stuktur komuniti burung di Semenanjung Malaysia dan membantu dalam merangka amalan pengurusan yang baik untuk memulihara kepelbagaian biologi habitat. Kajian ini juga telah berjaya mengaplikasikan pelbagai pendekatan pengukuran kepelbagaian spesies dan mencadangkan cara-cara dalam mengaplikasikan pengukuran-pengukuran ini untuk menilai kumpulan fauna yang mempunyai kepelbagaian yang tinggi. Oleh itu, hasil kajian mestilah dirujuk kerana kajian ini telah menilai secara terperinci pelbagai cara mengukur kepelbagaian dan komuniti struktur burung di Semenanjung Malaysia.

BIRD COMMUNITY STRUCTURE AND DIVERSITY IN PENINSULAR MALAYSIA

ABSTRACT

Peninsular Malaysia has rich and diverse flora and fauna. Much of these have yet to be documented. The avifauna is an important group that has received little attention, ecologically in this country. Different approaches of diversity measurements are presented in this thesis in order to evaluate the bird diversity in natural and man-made habitats. The objectives of this study are to determine the current bird species composition and diversity, to analyse β-diversity of birds, to investigate patterns of rarity among birds in natural habitats, and to study the contribution of rice fields to the bird diversity in Peninsular Malaysia by using multiple diversity measurements. The presence/absence data were obtained from primary (2002-2013) and secondary sources (1992-2015) recorded from 53 sites of natural habitats. Primary and secondary of bird data were also collected since year 2013-2014 from 83 sites of rice fields in nine states, Peninsular Malaysia. Point counts and mist-netting methods were used for bird census. Species accumulation curve was plotted to describe the species composition of birds. Seven species estimators were performed to estimate the current bird species richness and evaluate estimators' performance. The β-diversity was described through calculation of variation, turnover, and taxonomic similarity. The pattern of rarity among forest birds were determined by using Rabinowitz's seven forms of rarity. Meanwhile the contribution of rice fields on the total bird species in Peninsular Malaysia was analysed by using taxonomic distinctness measures. Four hundred and thirty eight bird species were recorded from 53 sites of study areas. The MMMeans estimated 482 bird species for natural habitats of Peninsular Malaysia. The β-diversity analysis showed that bird diversity was negatively correlated with distance but positively influenced by elevation, whilst taxonomic similarity suggests that based on the presence of birds from order Passeriformes, the west region displayed the greatest beta diversity with score of 0.797. In terms of rarity, 46 resident birds were categorised as the rarest bird species which has a scarce population size, restricted habitat specificity, and narrow distribution range. Result from the functional diversity analysis showed that rarity in birds easily occurred when the species are categorised as ‘isospecies’, understorey species, frugivores, and common resident of high altitude natural habitats. In our traditional landscape, rice fields have a significant contribution to the diversity of birds in Peninsular Malaysia, as many waterbird species were found here. The results obtained will enhance the understanding of bird community structure in Peninsular Malaysia and assist in developing good management practice for conserving such biodiverse habitats. This study also successfully applied different approaches of species diversity measurements and had suggested ways in applying these measurements to examine the high diversity group of fauna. Hence, the outcomes should be referred as the current study has thoroughly evaluated various ways of measuring bird community structure and diversity in Peninsular Malaysia.

CHAPTER 1

INTRODUCTION

1.1 Bird diversity in the tropics

Bird is one of the largest vertebrate group that have adapted to every unique environment although some species are found only in a very restricted areas while others have a wide range of habitat around the globe (Gaston, 2000). Birds are found almost everywhere on earth, and the exact number of total species is unknown since new species are still being discovered (Sætre et al., 2001; Robson, 2008; Alström et al., 2010). To date, there are 10,814 known species of birds represented by 240 families and 2292 genus in the world, 17 years after reaching 9,000 species in 1999 (May, 1992; Gill & Donsker, 2016). According to the International Ornithologists' Union, approximately 20,500 subspecies of birds have been discovered (Gill & Donsker, 2016).

Nowadays, bird classification is not dependent on the overall structure, plumage characteristics, and habits since these are strongly influenced by sexual selection, which can lead to misidentification; however with more advanced technology of DNA analysis many new bird species are being discovered (Kress et al., 2015). As an example, results from mitochondrial DNA sequence analysis showed that a sympatric population of Pied Flycatcher, *Ficedula hypoleuca* and Collared Flycatcher, *Ficedula albicollis* contains another black and white new species of *Ficedula* known as the Atlas Flycatcher, *Ficedula speculigera* (Sætre et al., 2001). Mahood et al. (2013) also discovered a new species of lowland tailorbird from the Mekong floodplain of Cambodia using genetic analysis to support evidence of study, instead of using the straightforward morphological comparisons. Accordingly, more new bird species could be discovered.

Tropical countries that have broad range of habitats such as lowland forest, montane forest, hill dipterocarp forest, mangrove forest, peat swamp forest, gardens, and orchards certainly supports a variety of bird species (Hughes et al., 2002; Jetz & Rahbek, 2002; Nagelkerken et al., 2008; Peh et al., 2011). The chances of getting new species with identification aid from DNA analysis in the tropics has been increasing lately. As an example, with the utilisation of DNA analysis, scientists have discovered a new species known as the Limestone Leaf Warbler, *Phylloscopus calciatilis* that is closely related with Sulphur-breasted Warbler, *P. ricketti* and Yellow-vented Warbler, *P. cantator* (Alström et al., 2010). This species that was found in the central and northern Vietnam, and central and northern Laos, is believed to have a restricted breeding range in limestone karst environments (Alström et al., 2010).

Furthermore, the taxonomic classification also changes from time to time. Robson (2008) documented 1,327 bird species in his second edition of book entitled '*A field guide to the birds of South-east Asia*', and listed all new species to the region, omitted in accurate classification , and made changes in nomenclature since the previous edition of the book. Thirty two species were completely new taxa to the region of South-east Asia; six species were omitted due to the recent taxonomic change, 48 additional species to the region due to taxonomic splits, and more than 150 species of existing species with changes in nomenclature due to taxonomic splits Robson (2008). Most of the variations were because of the recent taxonomic changes and the resolution of gender issue (Robson, 2008).

1.2 Bird diversity in natural habitats of Peninsular Malaysia

The terrestrial ecosystems in Peninsular Malaysia include various types of natural and man-made habitats ranging from the coast to highland. The varieties of natural habitats that exist in Peninsular Malaysia such as lowland rainforest, hilly forest, mountain rainforest, and mangrove forest have become home to a variety of birds (Nagelkerken et al., 2008; Nur Munira et al., 2011; Peh et al., 2011). Natural habitats of Peninsular Malaysia supports a large number of resident birds, and receives hundreds of migratory species that migrate from northern hemisphere to southern hemisphere during the winter migratory season (September-March every year) (DeCandido et al., 2004). Natural habitats also record the highest number of bird species compared with man-made habitats (i.e. oil palm plantations and rice fields) (Nur Munira et al., 2011).

Seven hundred and twenty six bird species have been recorded throughout the country to date (eBird, 2016). In Peninsular Malaysia, Selangor has recorded the highest number of bird species with a total of 529 species were known to date, followed by Pahang (517), and Perak (515) (Figure 1.1). Most of the birding hotspots in Peninsular Malaysia are characterised as natural forests and highland areas. Among the top birding hotspots, include (1) Taman Negara, Kuala Tahan, Pahang, (2) Fraser Hill, Pahang, (3) Gunung Panti Forest Reserve, Johor, (4) Kuala Selangor Nature Park, Selangor, and (5) Bukit Larut, Perak (Figure 1.2). Taman Negara is among the most important forest reserve in this country. Taman Negara is located at the centre of Peninsular Malaysia and spreads over 4343 km^2 within areas of three states namely Kelantan, Terengganu, and Pahang (Latif et al., 2012). Taman Negara is also known as one of the world's oldest rainforest estimated about 130 million years (Latif et al., 2012) and this forest reserve is home to 388 bird species (Figure 1.2) (eBird, 2016).

These forest reserves are important for the survival of resident breeding bird species. The Blue-winged Pitta *Pitta moluccencis*, for example, was found to extend their breeding range to Taman Negara National Park, Pahang although previously known to breed only in the north of Peninsular Malaysia (Hutchinson & Mears, 2006). Besides, highland areas such as Fraser Hill, Cameron Highland, and Bukit Larut are important areas for high latitude bird species such as Silver-eared Mersia (*Leithrix argentauris*), Mountain Bulbul (*Ixos mcclellandii*) and Common Green Magpie (*Cissa chinensis*) (Robson, 2008).

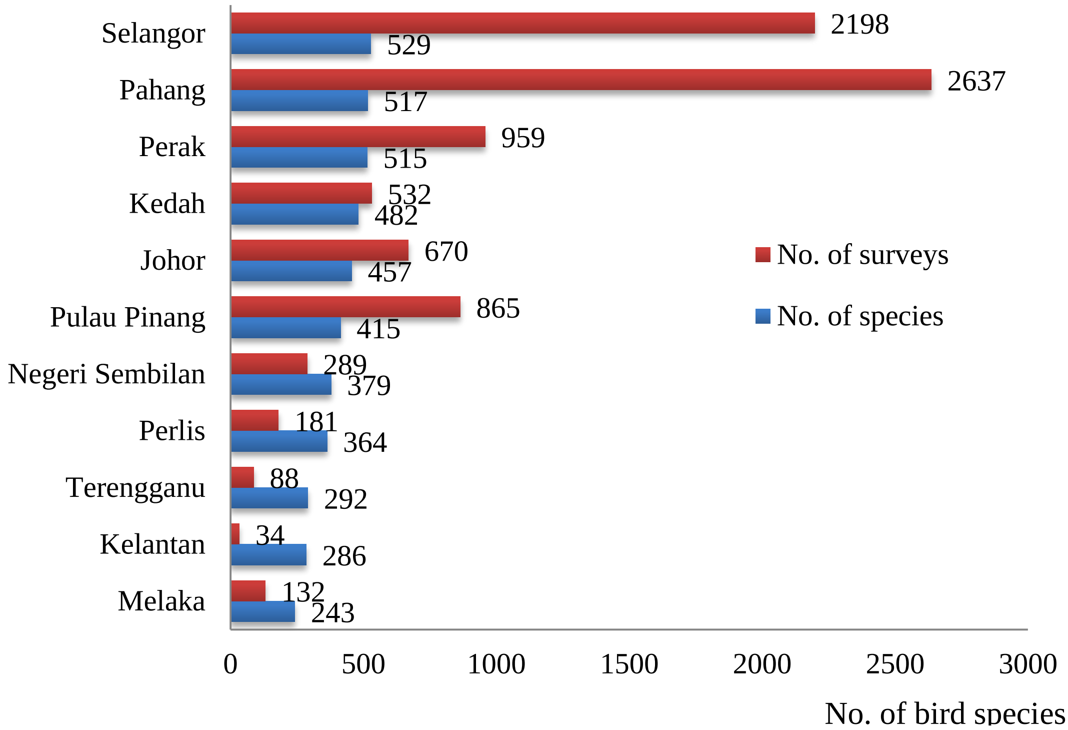

Figure 1.1 Total number of bird species recorded and field observations according to states in Peninsular Malaysia (eBird, 2016).

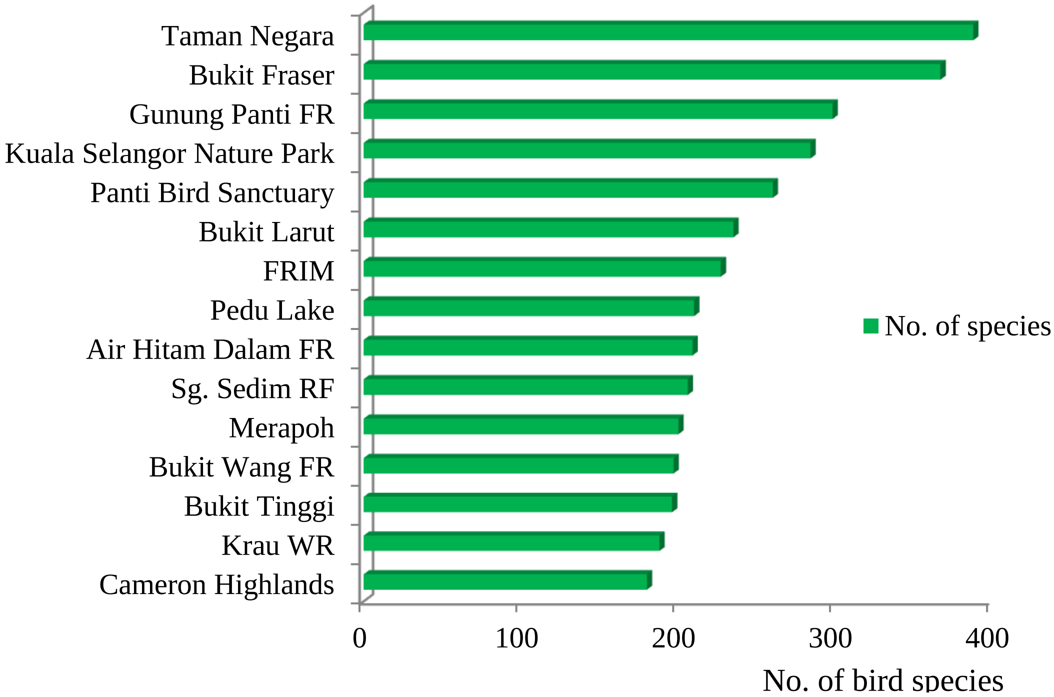

Figure 1.2 Total number of species recorded in 15 birding hotspots in Peninsular Malaysia. Seven hundred and twenty six bird species have been recorded throughout the country to date (eBird, 2016).

Nevertheless, human activities and deforestation have been among the major threatening factors on the decline of birds in this country (Wilcove et al., 2013). Prior to land conversion, the activities are heightened, and it is very important to measure the diversity of birds in their natural habitats in order to obtain more information for conservation purposes. Most of the recent studies on birds conducted in Malaysia mainly focused on the affected forest habitats caused by activities such as logging and habitat conversion (Soh et al., 2006; Edwards et al., 2013). There is a relative paucity of studies on the detail measure of bird diversity in their natural habitats in Peninsular Malaysia (Rahman, 2002; Sheldon et al., 2009a). Detail and accurate biodiversity assessment is crucial in diverse natural habitats; however there is lack of documentation on this matter.

1.3 The importance of birds

Birds play an important role to the environment and are beneficial to humans. Bird is an important dispersal agent for flora and fauna. The frugivores bird species such as flowerpeckers, bulbuls, and hornbills are seed dispersers or pollinators, which also influence the pattern of seed distribution and thus formation of forest structure (Moermond & Denslow, 1985; Clark et al., 2001). A study on bats and birds at pastures in the tropical rainforest in Mexico also revealed that both the taxa are important in spreading the seeds of pioneer and umbrella species (ficus, shrubs, herbs, and epiphytes) in pastures which in turn connect forest fragments and conserve forest diversity (Galindo-González, 2000). Birds also help in the dispersal of small creature in the forest such as Hemlock Wooly Adelgid *Adelges tsugae*, (a small aphidlike insect), from one area to another (Orwig et al., 2002).

Birds are also important in regulating the populations of insects. Murakami and Nakano (2002) conducted a manipulative field experiment to determine the effect of birds on the insect herbivore population in the riparian forest. The study revealed that the insect herbivore population near the stream areas was more influenced by bird predation compared to the upland forest (Murakami & Nakano, 2002). Instead of regulating the population of insect, raptors (bird of prey) in rice fields were found to help farmers control the population of pests. Field observation in the rice fields of Permatang Damak, Penang, by Nur Munira et al. (2014b) found that raptors such as Brahminy Kite, *Haliastur indus* and Black-shouldered Kite, *Elanus caeruleus* often prey on rodents especially during harvesting season.

In addition, birds are frequently chosen as indicators to predict the effects of environmental stress. It is the best indicator for habitat loss and food availability (Lim & Sodhi, 2004; Lehmkuhl et al., 2007). Bird is an animal group that is always documented by many studies on habitat destruction (Naidoo, 2004; Waltert et al., 2005; Ko et al., 2009). As explained by Lawton et al. (1998) and Louette et al. (1995), birds are frequently depicted as the indicator or ‘flagship taxa’ in biodiversity inventories because birds are widespread and present in most habitats. Birds are easy to observe or detect compared to the other fauna due to their loud vocalization; most of them have bright colour patterns and they are abundant in many habitat.

High bird diversity in Peninsular Malaysia is the main reason that Malaysia is the ultimate birdwatching paradise for recreational activity. There are 55 Important Bird Areas in Malaysia, whereby 18 areas are located in Peninsular Malaysia (Yeap et al., 2007). Birdwatching activity provides awareness among citizens to become receptive on the importance of nature and wildlife. The collaboration between local authorities and non-governmental organisations (NGOs) on the establishment of bird-related events such as Raptor Watch in Tanjung Tuan, the Fraser's Hill International Bird Race, and the Wing of Kuala Kubu Baru provides an avenue for bird enthusiasts from around the world to return every year to Malaysia (Kudus, 2011). The annual project of "My Garden Birdwatch" organised by Malaysia Nature Society (MNS) and its Bird Conservation Council has also encouraged Malaysians from all ages to be more aware on the existence of birds in their own backyard (Tiah, 2015).

For many centuries, human and birds are intertwined. Many people see birds as a symbol of freedom and strength. However, some people believe that blackbird denotes bad luck whereas white birds and feathers denote good fortune. Bird symbols are often used as name for sports team, images on stamps, coins, paintings, songs, cereals, automobile, greeting cards and shoes. In East Malaysia, Sarawak is known as the land of hornbills where eight out of 54 species hornbills in the world are found (Bennett et al., 1997). The Rhinoceros hornbill is the official emblem of the state of Sarawak, and important as a cultural symbol for the people of Sarawak especially the Dayak communities (BPO, 2016).

1.4 Contribution of rice fields on bird diversity in Peninsular Malaysia

Rice field is a temporary wetland landscape that is important as a feeding ground and stop over area for various type of birds such as waterbirds, raptors, pigeons, sparrows, and munias (Nur Munira et al., 2014a). The environment of rice fields are repeatedly changing due to the influence from human activities i.e. ploughing, seasonal flooding, and planting (Stafford et al., 2010). Thus, rice fields are a unique habitat where every stage of planting attracts different bird groups for foraging (Stafford et al., 2010). This was evident by with the study by Nur Munira et al. (2014a) where distinct variation of bird richness and abundance was observed in every planting stage. Besides, a study on the use of rice fields by raptors in northern Peninsular Malaysia revealed that at least 10 migratory raptors were observed which include two vulnerable raptor species, i.e., Greater-spotted Eagle, *Aquila clanga* and Eastern Imperial Eagle, *Aquila heliacal* (Nur Munira et al., 2014b). This had proven that rice fields play an important role in providing suitable habitats for foraging, shelter, and breeding activities for diverse birds (Wood et al., 2010).

Between 2010 and 2016, only a small number of researches related to the bird diversity of rice field were conducted. Example of studies that have been carried out within this period interval were bird use of rice fields in Korea and Japan (Fujioka et al., 2010), bird use of rice fields in the Indian subcontinent (Sundar & Subramanya, 2011), birds of rice fields in the Americas (Acosta et al., 2010) and the temporal distribution of birds in rice-growing landscape in northern Peninsular Malaysia (Nur

Munira et al., 2014a). Nur Munira et al. (2014a) also state the lack of ecological study on bird's assemblages in the rice fields of Malaysia.

These studies have highlighted the importance of rice field cultivation areas that served as breeding habitats for waterbirds. Rice fields can also uphold the most diverse and abundant amount of breeding waterbirds in the world as shown in Southwestern Louisiana (Pierluissi *et al*., 2010). This has proven that rice field ecosystem exhibits a good habitat to support diverse bird groups. Based on this information, more studies should be conducted in order to ascertain the current situation of bird diversity especially in Peninsular Malaysia's rice fields. This study aims to identify the contribution of rice fields on the total bird diversity in Peninsular Malaysia.

1.5 Rationale

Recent studies on birds in Malaysia revealed that, few approaches of bird measurements have been conducted. Most studies on birds in various habitats have used the common diversity measures such as Simpson's diversity index (Rahman, 2002), Shannon-Wiener formula (Sheldon et al., 2009a; Nur Munira et al., 2011), and Fisher's alpha (Bing et al., 2013). Bird diversity study in Paya Indah Wetland Reserve have used the regular measurement as most of the previous studies i.e. Shannon's and Simpson's index for diversity indices, Margalef's and Menhinik's index for richness indices, and McIntosh's and Pielou J index for evenness indices

(Zakaria et al., 2009). The simplest data analysis i.e. describing bird diversity in percentage was also found in the study of bird diversity in Kenaboi Forest Reserve, Jelebu (Ramli et al., 2009)

However, there were several studies on bird diversity in Malaysia that used species estimators to determine the estimated species richness (Peh et al., 2005; Peh et al., 2006). This species estimator is very useful for ecologists to estimate the total number of species in any particular area from limited dataset or with different approaches (Herzoq et al., 2002). Since this approach of measurement has only been applied to the birds of logged forest and mixed-rural habitats in southern Peninsular Malaysia (Peh et al., 2005; Peh et al., 2006), the present study aims filled this gap by applying a similar approach to the wider range of birds in natural habitats throughout Peninsular Malaysia. The estimation of total number of species in natural habitats is important to be examined, as it can aid in formulating management actions that will provide maximum benefits for bird communities.

Many previous studies have also been restricted on the local diversity or known as alpha diversity (Styring & Ickes, 2001; Zamri & Zakaria, 2002; Styring & Zakaria, 2004). According to Jankowski et al. (2009), the investigation of bird diversity should not be restricted to only within the habitat but also important to assess the diversity among habitats on a landscape scale. Thus, beta diversity across the region in Peninsular Malaysia is another important aspect to be discovered in this study. To date, there have been no attempts to evaluate beta diversity on a broader scale that involve natural habitats in Peninsular Malaysia. The investigation of beta diversity is able to provide additional knowledge for better understanding of birds in natural habitats across the region of Peninsular Malaysia.

The assessment based on the incidence data is frequently limited to the percentage of species or family list and often unable to generate optimal information from the abundance data (Ramli et al., 2009). However, this study fills the gap by analysing the incidence bird data in detail to generate maximum information that is believed to be useful in bird assessment. The pattern of rarity in birds is assessed from the incidence data, which is able to give better understanding on conservation actions (Brooks et al., 2002). In addition, functional diversity for each bird species can also be assessed through the incidence base data (Barbaro & Halder, 2008). This study also aims to analyse the functional life traits of rare species in order to link to their limited occurrences in natural habitats.

The incidence base data are further used to analyse the taxonomic distinctness of birds in natural and man-made habitats. This can be considered as a new tool for measurement of bird diversity in Peninsular Malaysia because measure of species richness (i.e. diversity indices) in the aforementioned habitat is a common objective. Investigation of bird diversity through taxonomic make-up in various habitats is an alternative method that gives meaningful information to species that are more taxonomically distinct (Xu et al., 2012). If two or more habitats have similar number of species richness, it is not necessary that all habitats are equally diversified, but one habitat may have species that are taxonomically related to one another or vice versa (Warwick & Clarke, 1998).

1.6 Thesis outline

This thesis consists of five general chapters and five research chapters. The first general section, Chapter 1 focuses on the introduction of avifauna at global and local scale as well as overview on the contribution of rice field habitats on the diversity of avifauna in Peninsular Malaysia. Chapter 2 presents literature review of this study. Chapter 3 describes the general materials and methods used. General chapters also include Chapter 9 where general discussions from all research chapters are consolidated and Chapter 10 provides general conclusions of the study.

Chapter 4 to 8 are the main research chapters of this thesis. Chapter 4 is the overview on the species richness and community structure of bird in natural habitats of Peninsular Malaysia. This chapter describes the species accumulation curve in order to determine the sampling effort sufficiency, identifies the bird status (i.e. residential status, population trend, and IUCN status), and overview of bird occurrence across study sites.

Chapter 5 thus estimates the bird species richness for natural habitats in Peninsular Malaysia. Seven types of estimators are used to analyse the bird incidence data obtained from both primary and secondary sources. The performance for each estimator is evaluated in order to choose best performing estimators. This chapter also discusses whether species richness estimator tools are able to generate reasonable estimations of diversity although the data used may have been obtained through different sampling efforts. Assessment on regional biodiversity of birds in natural habitats in Peninsular Malaysia is explored in Chapter 6. Spatial patterns of bird community structure are documented using a range of methods and patterns of bird diversity within and between regions and throughout Peninsular Malaysia are discussed. It is predicted that bird species diversity between areas can be affected by distance, whereby close distance sites show high similarity in bird diversity and vice versa.

Chapter 7 further explores the pattern of rarity among birds based on geographic range, habitat specificity, and local population. The functional diversity for each rare species found in natural habitats is also analysed in this chapter. It is predicted that some species are common and abundant whilst there is a large portion of rare species found in natural habitats. Chapter 8 is the case study in order to ascertain the contribution of rice fields on bird diversity in Malaysia. Bird diversity in every stage of planting activities is also assessed in this chapter. Taxonomic relatedness of bird species in natural habitats and rice fields is explored in this chapter.

The predominant goal of this study is to measure bird diversity and analysis of community composition and community assemblage structure among birds across natural habitats of Peninsular Malaysia. Various measurements are applied to the bird data, which is hoped to enhance understanding and knowledge of the diversity and assemblage structure of bird in natural habitats of Peninsular Malaysia. In future, these data can be used as a reference to the other similar studies in order to explain the vast diversity of avifauna in such systems.

1.7 Objectives

The primary objectives of the study according to each research chapter are as follows:

1. To determine the status of birds and population trend based on IUCN Red List at natural habitats of Peninsular Malaysia from primary and secondary data.

2. To estimate the total number of bird species in natural habitats by using seven types of non-parametric estimators.

3. To analyse the beta diversity of bird communities among study areas based on turnover and variation concepts.

4. To identify the forms of rarity among bird species in natural habitats of Peninsular Malaysia by using the rarity classification system.

5. To compare the bird taxa in natural habitats and rice fields in order to see the contribution of bird species in the rice fields to the diversity of birds in Peninsular Malaysia.

CHAPTER 2

LITERATURE REVIEW

2.1 Birds in natural habitats

Tropics consist of a region surrounding the equator that includes Tropical Andes, Madagascar, Caribbean, Indo-Burma, Western Ghats and Sri Lanka, Wallacea, Philippines, and Sundaland (Brummitt & Lughadha, 2003). These lands are among the 25 biodiversity hotspots in the world that are homes to 2,821 endemic birds (Myers et al., 2000). Tropical Andes records the highest number of bird species with total of 1,666, and 677 are endemics (Myers et al., 2000). The Sundaland that encompasses the Peninsular Malaysia on the Asian mainland, the large islands of Borneo, Sumatra, Java and its surrounding islands consist of a total of 815 bird species, whereby 139 are endemics to this region (Myers et al., 2000). The number of bird species records an increase from time to time, hence discovery of new bird species are occasionally described (Sheldon et al., 2009b; Lohman et al., 2010).

In tropical regions of South-east Asia, bird diversity is very high across the countries (Myers et al., 2000; Sodhi et al., 2004a; Robson, 2008). For example, Peninsular Malaysia or West Malaysia is the southernmost extension of mainland Asia, which is located between Thailand and Singapore, harbours more than 638 species of birds (Strange & Jeyarajasingam, 1999). Although the landmass coverage of Peninsular Malaysia is small (approximately 131, 235 km^2), factors such as habitat variation, its location near to the equator, and stable tropical climate have promoted high bird diversity in this country (Hughes et al., 2002). The bird composition in Peninsular Malaysia has similarity with other Sunda subregion areas (i.e. Sumatra, Java, and Borneo) because during the last Ice-Age, approximately 15,000 years ago, when sea-levels was much lower than today, the landmass in Sunda subregion was connected and probably bird species in the subregion were shared (Sodhi et al., 2004a). The Sunda subregion recorded 129 endemics while only two endemics were found in Peninsular Malaysia (i.e Mountain Peacock-Pheasant, *Polyplectron inopinatum* and Malayan Whistling Thrush, *Myophonus robinsoni*).

Myers et al. (2000) stated that the Sundaland (including Peninsular Malaysia) was listed among the 25 biodiversity hotspot areas in the world. Bird is a wonderful fauna that lives in various habitats. Natural habitats in Peninsular Malaysia comprised of several types of forests such as lowland, montane, mangrove and peat swamp forest. Natural habitats have contributed the large proportion of bird species compared with man-made habitats include plantations (monoculture), orchards, and mix-shrubs (Peh et al., 2005, Aratrakorn et al., 2006; Nur Munira et al., 2011). Conducive environments in natural habitats offer high availability of food sources (Iwata, 2003), stable climate for egg incubation and hatchery (Zanette & Jenkins, 2000), and wide ranges of habitat niches (Siebert, 2002) to support a variety of bird species to live in this habitat.

Natural habitats especially rainforests play a vital role in serving as home, shelter, and provide abundance of food sources to resident and migratory birds. Birds that can be found in natural habitats are categorised as either common, rare, or endemic birds. A study on bird diversity in Kenaboi Forest Reserve, Jelebu, Negeri Sembilan recorded 51 species that were commonly found in the study area (7-45 occurrences), 49 uncommon (3-6 occurrences), and 46 considered rare (unique and duplicate) (Ramli et al., 2009). According to Ramli et al. (2009) although the Kenaboi Forest Reserve had been extensively logged for the past 20 years, this forest reserve is able to regenerate and provide sufficient resources for 152 bird species including 31 near-threatened species.

Continuous habitat destruction and degradation, over-exploitation (e.g. urbanisation), presence of exotic species, disease, pollution and contaminants, climate change, and other threats have resulted in the decline of the population and extinction of birds worldwide (Baillie et al., 2004; Sodhi et al., 2010). There are many reviews on bird diversity from 2000 to 2015 that have discussed the effects of forest fragmentation on bird species richness (Echeverría et al., 2006; Flaspohler et al., 2010), effects of plantation on bird diversity (Fitzherbert et al., 2008), bird species composition and feeding guilds in wetland reserve (Zakaria & Rajpar, 2010), disappearance of insectivores birds from tropical forest fragements (Şekercioḡlu et al., 2002), and response of mixed-species flocks to habitat alteration and deforestation (Zuluaga & Rodewald, 2015). It is concluded that bird diversity is significantly affected by human activities and deforestation.

2.2 Estimating bird species richness

The total number of bird species richness in Malaysia remains unknown. To date, more than 746 bird species have been recorded in Peninsular Malaysia, Sabah and Sarawak in the Borneo Island (MacKinnon & Phillipps, 1993; Wells, 1999 & 2007). In Malaysia, several studies have employed species estimator analysis in order to estimate bird species richness. Peh et al. (2006) conducted a study on the conservation value of degraded habitats for forest birds in southern Peninsular Malaysia. In their study, nine types of non-parametric estimators are used (i.e., ACE, ICE, Chao1, Chao2, Jackknife1, Jackknife2, MMMean, MMRun, and Bootstraps) to estimate forest bird species that were present in rubber tree plantations, oil palm plantations, and open areas. The results showed that these habitats supported 46-76 bird species which highest in rubber tree plantations compared to oil palm plantations and open habitats (Peh et al., 2006).

A year earlier Peh et al. (2005) conducted a study on the persistence of primary forest birds in selectively locked forests and mixed-rural habitats in Johor (southern of Peninsular Malaysia). This study used non-parametric estimators including incidence-based estimator Chao2, incidence-based coverage estimator ICE and Michaelis-Menten model based estimator MMMean to estimate bird species richness. The choice of these three estimators were based on the best performance of the estimators in predicting tropical bird species as studied by Walther & Martin (2001), Matlock et al. (2002), and Herzog et al. (2002). Soh et al. (2006) also used non-parametric estimators (i.e. ACE, ICE, Chao1, Chao2, Jack1, Jack2, Bootstrap, MMRuns, MMMean) for bird study in montane areas of Peninsular Malaysia. According to Soh et al. (2006) several estimators were employed since the performances of different estimators vary according to data sets. However, none of these bird studies in Peninsular Malaysia evaluated the performance of the estimators used.

In year 2011, a group of researchers from Universiti Putra Malaysia conducted a study on the conservation value of oil palm plantation estates and logged peat swamp forest for birds in the west coast of Peninsular Malaysia (Azhar et al., 2011). This study used four mean of abundance estimators (ACE, Chao1, Jack1, and Bootstrap) due to the unstandardized sample size among site types, and to estimate bird species in the study sites. Recently, Azhar et al. (2015) also used Chao1 and ACE estimators to estimate understory birds, fruit bats, and butterfly that exist in the oil palm agricultural matrix. Both of these studies used abundance data, and none of bird studies in Peninsular Malaysia attempted to estimate species richness using the presence/absence data.

Other studies also used non-parametric estimators in other group of fauna such as a study on ground-dwelling ants in Sabah by Brühl & Eltz (2010) and study on tree species diversity in Borneo Island by Cannon et al. (1998). According to Brühl & Eltz (2010), Jack2 estimates the highest species richness, i.e. 48, while MMMean estimates the lowest, i.e. 25 ant species in oil palm plantations. Meanwhile a study by Cannon et al. (1998) stated a total of 329 and 340 tree species estimated by Chao2 in unlogged forest and eight-year logged forest, respectively.

According to Colwell & Coddington (1994), Bunge & Fitzpatrick (1993) and Magurran (2004) several approaches have been used in estimating species richness and are categorised as follows: (1) extrapolation of species accumulation curves, (2) fitting parametric distributions of relative abundance, and (3) using non-parametric estimators based on abundance or incidence based data of species among samples. Nonetheless, non-parametric estimators became the most preferred approach by researchers in biodiversity task for more than a decade (Walther & Martin, 2001). The non-parametric estimators used rare species information of assemblage-singleton and doubleton (those represented by one or two individuals) or unique and duplicate (those represented once or twice) to predict the number of species that were not presented in the dataset (Gotelli & Colwell, 2001). Examples of studies that used non-parametric species richness estimator in their studies are shown in Table 2.1.

Table 2.1 Various ecological studies that used species richness estimator over the last two decades.

Source	Country	Organism	Sampling method(s)	Evaluation on estimator	Performance of estimator
Walther & Morand (1998)	UK & France	Parasites from different host (woodcreepers, fish, frogs, rabbits and tawny owls)	Secondary data	Bias and precision	Chao2 and Jackknife 1 estimators performed best for real data sets
Toti et al. (2000)	USA	Spider	Aerial hand collection, ground hand collection, beating, Tullgren funnel litter extraction, and sweep-netting	Reach asymptote of estimator curve with fewer samples and close to reasonable visual asymptote	Michaelis-Menten means (MMMean) performed better than other estimators
Chiarucci et al. (2001)	Italy	Plant	Plots	Relative error (RE) and square relative deviation (SRD)	Jack 1 and Jack 2 had the best performances
Melo & Froehlich (2001)	South-east Brazil	Macro-invertebrate	Using U-net	Based on four criteria: 1. The smallest sub-sample size needed to estimate total richness in the sample, 2. Constancy of this size, 3. Lack of erratic behaviour in curve shape, and 4. Similarity in curve shape through different data sets	Bootstrap estimator was the best estimator followed by Jack2.

Table 2.1 Continued

Source	Country	Organism	Sampling method(s)	Evaluation on estimator	Performance of estimator
Walther & Martin (2001)	Canada	Birds	Point counts	Bias and precision	Chao2 was the best estimator followed by Jackknife2
Brose (2002)	East Germany	Carabid beetle	Pitfall trapping	Accuracy and precision	Chao2 was the most accurate and precise estimator
Herzog et al. (2002)	Bolivia	Birds	Species-list method (visual and acoustical observations) and mist-netting	Accuracy, sensitivity to sample size, sensitivity to true species richness and the influence of underlying species-abundance or species-detectability distribution	MMMean performed best for empirical and most simulated data sets
Longino et al. (2002)	Costa Rica	Ants	Fogging, Malaise, Berlese, Winkler, Barger, Thompson, Longino, and other	Evaluation through data partitions and sample-based rarefaction plots	Tested only on ICE and MMMean
Sørensen et al. (2002)	Tanzania	Spiders	Pitfall traps, cryptic searching, sweep netting, ground & areal hand collecting, and vegetation beating	Good estimator should asymptote accurately and early	Chao1 performed better than other estimators

Table 2.1 Continued

Source	Country	Organism	Sampling method(s)	Evaluation on estimator	Performance of estimator
Foggo et al. (2003)	United Kingdom	Reef fish, Beach macrofauna, and Estuarine Oligochaetes	Sampling used deep box core and secondary data	Bias, precision, and accuracy	Chao1 represents the best estimator among others
Hortal et al. (2006)	North Atlantic	Arthropod	Transects and pitfall traps	Bias and precision	ACE and Chao1 showed the best performance throughout the different sampling effort unit
González-Oreja et al. (2010)	Northern Spain	Plant	Quadrat sampling with different environmental conditions	Bias, precision, and accuracy	Jackknife 1 was the best estimator