Institute of Biodiversity and Environment Conservation

DIVERSITY AND FEEDING GUILDS OF UNDERSTOREY BIRD IN AN OIL PALM PLANTATION AND ADJACENT PEAT SWAMP FOREST IN BETONG DIVISION, SARAWAK, MALAYSIA

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DECLARATION

I hereby declare that the work entitled "**Diversity and Feeding Guilds of Understorey Bird in an Oil Palm Plantation and Adjacent Peat Swamp Forest in Betong Division, Sarawak, Malaysia"** is my original work. I have not copied from any other student's work or from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for me by any other person. I also declare no portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification to this university or any other institution of higher learning.

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Diversity and Feeding Guilds of Understorey Bird in an Oil Palm Plantation and Adjacent Peat Swamp Forest in Betong Division, Sarawak, Malaysia.

ABSTRACT

One of the biggest concerns regarding the conversion of tropical forest into oil palm plantation is the expansion of plantation into peatland and the impact it has on species diversity. This study is important to confirm what has been reported for oil palm on minerals soils that bird diversity is reduced in oil palm plantation and no studies of similar nature have been conducted on peatland in Sarawak.

The first objective of this study is to document the species diversity of understorey bird in oil palm plantation planted on peat and adjacent peat swamp forest in Betong Division, Sarawak. A total of 48 species were captured using mist-nets over a period of 34 days of which 30 species were recorded in oil palm plantation and 31 species were recorded in adjacent peat swamp forest. The 48 species of bird recorded in this study were further categorized into forest bird and garden bird. Forest bird species are reduced in number as we move from inside the peat swamp forest into oil palm plantation while garden birds were present only in oil palm plantation. The total species and number of individuals of garden birds increased from boundary towards the centre of the oil palm plantation.

The second objective was to determine the direction and frequency of bird crossing between oil palm plantation and adjacent peat swamp forest. Results showed that there were significantly more birds hitting the boundary nets from the oil palm plantation side. A significantly higher frequency of bird crossed the boundary site in the morning compared to midday and late afternoon, presumably for foraging purpose.

Finally, the third objective of the study was to determine the reason behind *Pycnonotus goiavier* abundance in oil palm plantation hence a study on their dietary habits was conducted. *Pycnonotus goiavier* was found to actively select insects from the Order Coleoptera as its main food in oil palm plantation, followed by Homoptera, Diptera, Hemiptera and Hymenoptera. However, this bird completely avoids feeding on insects from Order Odonata, Orthoptera, Dictyoptera and Lepidoptera. Hence, oil palm habitat is providing ample food resources such as insect for this bird species to continue their survival.

This study showed that understorey bird species diversity is significantly lower in oil palm plantation than in adjacent peat swamp forest and this finding supported what has been reported for oil palm on minerals soils. Therefore, plantation management should include conservation efforts for the birds both within and in surrounding oil palm areas in order to create biodiversity-friendly plantations besides increasing oil palm yield.

Keywords: understorey bird, oil palm plantation, peat swamp forest, *Pycnonotus goiavier*

Kepelbagaian Spesies dan *Guild* Pemakanan Burung di bawah Kanopi di Ladang Sawit dan Hutan Paya Gambut, Betong, Sarawak

ABSTRAK

Salah satu perkara utama mengenai penukaran hutan tropika ke ladang sawit adalah perluasan perladangan ke hutan paya gambut dan kesannya terhadap kepelbagaian spesies. Kajian ini adalah penting untuk mengesahkan apa yang telah dilaporkan di ladang sawit tanah mineral bahawa kepelbagaian burung berkurangan di ladang sawit dan tiada kajian yang serupa telah dijalankan di kawasan paya gambut di Sarawak.

Objektif pertama kajian ini adalah untuk mendokumentasikan kepelbagaian spesies burung di bawah kanopi dalam ladang sawit paya gambut dan hutan paya gambut bersebelahan di Bahagian Betong, Sarawak. Sebanyak 48 spesies burung telah ditangkap menggunakan jaring samar dalam tempoh 34 hari. Kajian menunjukkan bahawa tidak banyak perbezaan antara bilangan spesies di ladang sawit (30 spesies) dan hutan paya gambut (31 spesies) tetapi komposisi spesies berbeza dengan ketara daripada satu sama lain. Empat puluh lapan spesies burung direkodkan dalam kajian ini telah dikategorikan kepada burung hutan dan burung taman. Spesies burung hutan berkurangan dari dalam hutan paya gambut ke dalam ladang sawit manakala burung taman hadir hanya dalam ladang sawit sahaja. Jumlah spesies dan individu burung taman meningkat dari sempadan ke dalam ladang sawit.

Objektif kedua adalah menentukan hala tuju dan kekerapan lintasan burung antara ladang sawit dan hutan paya gambut di mana jaring samar telah didirikan selari dengan sempadan diantara dua habitat ini. Keputusan menunjukkan bahawa lebih banyak burung menuju ke arah hutan tanah gambut mencadangkan bahawa destinasi pilihan untuk

burung di bawah kanopi adalah hutan paya gambut. Selain itu, burung kerap menyeberangi sempadan pada waktu pagi berbanding tengah hari dan petang untuk mencari makanan.

Objektif terakhir adalah menentukan sebab burung Pycnonotus goiavier mendominasi ladang sawit dengan mengkaji tabiat pemakanan mereka. Survei serangga di ladang sawit menunjukan bahawa ia didominasi oleh Order Hymenoptera. Namun kajian menunjukkan bahawa burung ini secara aktif memilih serangga dari order Coleoptera sebagai sumber makanan utama mereka di ladang sawit, diikuti order Homoptera, Diptera, Hemiptera dan Hymenoptera tetapi spesies ini sepenuhnya mengelak memakan serangga dari Order Odonata, Orthoptera, Dictyoptera dan Lepidoptera. Oleh itu, habitat ladang sawit menyediakan sumber makanan seperti serangga yang mencukupi untuk spesies ini meneruskan kelangsungan hidupnya.

Kesimpulannya, kepelbagaian spesies burung di bawah kanopi di ladang sawit adalah rendah daripada hutan paya gambut dan kajian ini menyokong apa yang telah dilaporkan di ladang sawit tanah mineral bahawa kepelbagaian burung berkurangan dalam ladang sawit bebanding hutan. Oleh itu, pengurusan ladang perlu mengambil kira usaha pemuliharaan untuk burung di dalam dan di sekitar kawasan ladang sawit untuk mewujudkan konsep ladang mesra alam selain meningkatkan hasil kelapa sawit.

Kata Kunci: Burung di bawah kanopi, Ladang Sawit, Hutan paya gambut, Pycnonotus goiavier

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LIST OF ABBREVIATIONS

BOPE	Bratak Oil Palm Estate
CMC	Cermat Ceria Forest
DFM	Durafarm Oil Palm Plantation
IUCN	International Union for Conservation of Nature
LC	Least Concern
MPOB	Malaysian Palm Oil Board
MPOC	Malaysian Palm Oil Council
N	Total number of Individuals
NT	Near Threatened
PC	Phasic Community
RA	Relative Abundance
SWLPO	Sarawak Wild Life Protection Ordinance
UNDP	United Nations Development Programme
V	Vulnerable

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CHAPTER 1

INTRODUCTION

1.1 Background statements

The importance of peat swamps habitat for endemic species of flora and fauna is becoming an increasing concern (Phillips, 1998; Page *et al.*, 1999; Yule, 2010) because this ecosystem is rapidly vanishing due to agriculture development, logging, drainage and fire (Yule, 2009). Peat land is characterised as water-logged, with low nutrients and dissolved oxygen levels in acidic water. It is therefore a unique habitat for fauna and flora. Even though species diversity is lower than that of the lowland dipterocarp forest (Gaither, 1994; Myers, 2009) it can contain high portion of endemic species. Peat swamp forest is one of the major forest formations occurring in Borneo (UNDP, 2006). In Borneo, peat swamp forest occurs along the coast of Sarawak, Brunei Darussalam, Sabah and Kalimantan on low lying, poorly drained sites (Phillips, 1998).

About 2.43 million hectares of land in Malaysia is covered by peat. More than 65 per cent or about 1.59 million hectares of these peat swamp forests are located in Sarawak, less than 30 per cent in Peninsular Malaysia and the remainder in Sabah (Omar *et al.*, 2009). Large areas of peat swamp forest in Malaysia have already been cleared and drained for agriculture such as oil palm, sago, rubber, cocoa, coconut and other short term crops (Ipor, 2006), settlement and other human activities (UNDP, 2006). Recently however, the rate of conversion of these forests into oil palm plantation in particular is extensive (Ipor, 2006; Wetland International, 2010).

Oil palm is one of the most rapidly increasing crops in the world (Fitzherbert *et al*., 2008) and has provided the fastest increase in global oils and fats supplies over the last four decades. Malaysia and Indonesia are the world's largest producers and exporter of oil palm (Basiron *et al.,* 2004). In year 1917, oil palm was first planted commercially in Peninsular Malaysia to replace rubber plantation. During the earliest years of oil palm expansion, most of the oil palm was planted on suitable mineral soils. However, as the mineral soils become scarce, oil palm plantation expended to Sabah and Sarawak (Fitzherbert, *et al.*, 2008). Due to high demand on oil palm products every year, the total oil palm planted area increased continuously with some of the oil palms being planted on marginal soils such as peat (Omar *et al.*, 2010). Nowadays, the increasing pressures on peat swamp forests are not only due to high demand on timbers but for agriculture development such as oil palm plantation.

Malaysia oil palm planted area reached 5.08 million hectares in 2012, an increase of 76,820 hectares against 5.00 million hectares recorded in 2011. This was generally due to the rapid increase in planted area in Sarawak which recorded an increase of 54,651 hectares from 2011 to 2012. In 2012, Sabah is still the largest oil palm planted state with 1.44 million hectares of total oil palm planted area, followed by Sarawak with 1.08 million hectares (MPOB, 2012).

In 2011, from five million hectares of land that has been cultivated with oil palm, 13.3% per cent of it has been planted on peat. Sarawak still has the largest area of oil palm planted on peat, followed in order by Peninsular Malaysia and Sabah (Omar *et al.,* 2010). Currently, oil palm is the most economical crop for planting on peat soils as it gives the best return on investment when properly managed (Melling *et al*., 2006).

There has been a great deal of criticism by the environmentalist from non-government organization (Centre for Science in the public interest, 2005; Friends of the Earth Trust, 2007; Greenpeace, 2007; Mongabay, 2012) on conversion of forest to oil palm plantation because of its contribution to biodiversity loss based on studies conducted by Wakker (1998), Clay (2004), Fitzherbert *et al.* (2008), Koh and Wilcove (2008). In order to address this criticism the Malaysian government, through MPOB is committed to sustainable development through the protection of the environment and conservation of biodiversity and come up with evidence which support or disagree these allegations. Such evidence can only be obtained through systematic research on the effect of land conversion into oil palm plantation on fauna diversity and the process that maintain this diversity. Many species of forest birds cannot adapt to the disturbances caused by anthropogenic activities (Koh and Wilcove, 2008) such as conversion of forest to oil palm plantation and for these species conserving forested areas within plantation is crucial for their survival. Hence in this study, understorey birds have been suggested as indicator species because they are particularly sensitive to changes in habitat (understorey) conditions (Laurance, 2004).

There have been some studies on birds of peat swamp ecosystem (Bennett, 1994; Rahman and Tuen, 2006; Tuen, Abang and Tawan, 2008). About 239 species of birds have been reported in the peat swamp forest of Malaysia (Tuen, Abang and Tawan, 2008). Maludam National Park (MNP) is one of the parks in Sarawak that is made up of entirely peat swamp. A study by Chai in August 2004 showed that 166 species of birds were found in MNP, adding to an earlier report by Bennett (1994) of 22 species. A total of 679 birds from 67 species representing 25 families have been reported at a peat swamp forest in Kota Samarahan, Sarawak (Rahman and Tuen, 2006).

1.2 Problem statements

Peat swamp ecosystem is under threat either legally or illegally from logging, drainage, agricultural conversion, fire, fragmentation of habitats, hunting and collecting and reclamation for residential centres and industries. Thus there an urgent needs to document not only what species are found in peat swamp forest but also how the population dynamics are affected. Bird diversity is a good indicator of biodiversity in a certain area due to it being relatively easily-measured. In this thesis, the bird species diversity, richness and evenness in oil palm plantation and the adjacent peat swamp forest in Betong Division, Sarawak was investigated. Although bird studies have been carried out in oil palm estates in Peninsular Malaysia, Sabah and Sarawak, there is a lack of data on understorey bird diversity in oil palm planted on peat, bird diversity at varying distances from the boundary area and the feeding guild of bird. Accurate data on understorey bird species diversity, richness and evenness in oil palm plantation on peat and neighbouring forest is required to confirm what has been reported for oil palm on minerals soils that bird diversity is reduced in oil palm plantation. No studies of similar nature have been conducted in the area prior to this.

Little is known about the factors that are likely to influence the species diversity, richness and evenness of understorey birds in oil palm and adjacent peat swamp forests. Those factors might be availability of food (insects and fruits) or higher risk of predation by owl and eagles which can see their prey better in the more open structure of oil palm plantation as compared with close structure like forest. If oil palm plantation offers less food (insect and fruit) resources and low security from predator attack as compared with forest then low diversity and abundance of bird in oil palm plantation compare with forest is predicted.

Due to its proximity to DFM and Tradewinds Lingga I estate, CMC is fragmented forest that could be the habitat into which wildlife seek refuge when land was cleared to establish oil palm plantation. There would have been a transient increase in species richness and abundance in adjacent forest during the development phase of oil palm plantation. The species assemblages in adjacent peat swamp forest could also be used as indicator of what may have been in oil palm plantation site before it was cleared.

The boundary between oil palm plantation and adjacent forest is a transition zone which birds and other animals cross when moving between plantation and forest, especially species that use both habitats, for example, one for foraging and the other for sleeping and nesting. If mist-nets were to be erected parallel to this boundary then by looking at the direction birds hit the nets to make some inference about their choice of habitat. If the number of bird hitting the net from oil palm plantation is higher then we can infer that the bird's preferred destination is the forest.

Other than that, information on the diet of the dominant species of bird in oil palm plantation is necessary to find out what are the food resources that maintain their population in oil palm plantation on peat. Yellow-vented Bulbul (*Pycnonotus goiavier*) is the dominant group of bird in DFM (Amit, *et al.*, 2011) and the resources that sustain the abundance of this bird in this plantation is of considerable ecological interest. Hence through the stomach content analyses on dominant species of bird in oil palm plantation to find out what are the food resources that sustain this bird in oil palm plantation.

1.3 Objectives

The objectives of this study are to:

1. assess species diversity, richness and evenness of bird in an oil palm plantation and adjacent peat swamp forest.
2. determine the direction and frequency of bird crossing between the two ecosystems (oil palm plantation and adjacent forest).
3. determine the diet of Yellow-vented Bulbul, the dominant species in the oil palm plantation site.

1.4 Hypothesis

The hypotheses tested in this study were:

a. H_0: There is no significant difference in species richness, eveness and diversity indices between oil palm plantation and adjacent peat swamp forest.

   H_A: There is a significant difference in species richness, eveness and diversity indices between oil palm plantation and adjacent peat swamp forest.

b. H_0: There is no significant difference in species richness, eveness and diversity of bird at varying distance between oil palm plantation and adjacent peat swamp forest

   H_A: There is a significant difference in species richness, eveness and diversity of bird at varying distance between oil palm plantation and adjacent peat swamp forest

c. H_0: The number of birds hitting the net from plantation and from forest is the same

H_A: The number of birds hitting the net from plantation and from forest is different.

d. $H_{0:}$ The number of birds hitting the net in the morning, midday and late afternoon is the same.

$H_{A:}$ The number of birds hitting the net in the morning, midday and late afternoon is different.

CHAPTER 2

LITERATURE REVIEW

2.1 Tropical peat swamp forest

Peat swamp forests are waterlogged forests growing on a layer of decomposed organic matter from litter (dead leaves and plant materials) which then accumulates as peat up to 20 m thick (UNDP, 2006). As compared to temperate peats, tropical peats are quite different in term of their formation. According to Paramananthan (1998) tropical peats are generally formed from the accumulation of organic materials such as undecomposed, partially decomposed and highly decomposed plant remains and low growing plants such as *Sphagnum* spp., Gramineae and Cyperaceae while temperate peat formed from mosses. Tropical peat swamp forest is formed in the coastal lowlands between 4000 and 5000 years ago on top of marine sediments. Only a small area occurs up to 200 km inland located 10-30 m above sea level overlay with sand, gravel and clay (Sieffermann *et al.,* 1992**).** Sub-coastal and inland peat was formed began more than 10 000 years ago (Rieley *et al.,* 1992). Tropical peat swamp forest has very unique ecosystems the trees in this forest can grow up to 70 m high, besides the extreme condition of low pH from 2.9 to 4.0, low nutrient and anaerobic, unstable, spongy substrate of peat with 20 m deep or more. During wet season, the forest floor is flooded while during dry season the peat stays waterlogged (Yule, 2010).

Tropical peat swamp forest is one of the main forest formations in Borneo. In Borneo, this forest is well-represented along the coasts of Sarawak and Brunei, Sabah and Kalimantan (Phillips, 1998). In Sarawak and Brunei, six types of vegetation communities on tropical peat domes have been described by Anderson (1963). These phasic communities of plants from the edge to the centre of the dome is summarised in Table 1.

Table 1. Major characteristics of the peat swamp forest communities found on peat domes in Sarawak (Anderson, 1963)

Phasic community	Canopy Height (m)	Trees/ha >5cm dbh	Canopy and structure of forest
Mixed peat swamp forest (PC 1)	40-45	150-170	Mixed, uneven, dense middle and lower storeys
Alan (*Shorea albida*) Batu forest (PC 2)	40-45	150-170	Mixed, uneven, with prominent emergent. Dense middle/lower storeys
Alan Bunga Forest (PC 3)	50-60	85-125	Uneven, sometimes broken by gaps caused by lightning strikes and insect attack; middle storey almost absent with dense understorey frequently dominated by a single species
Padang Alan Forest (PC 4)	35-40	450	Canopy even and mostly unbroken, marked pole-lie structure
Padang Paya (PC 5)	15-20	1,000-1250	Dense even canopy with few emergent, herbaceous flora largely absent
Padang Keruntum (PC 6)	Up to 7	Mostly shrub-like forms	Open aspect with only one tree species reaching up to 20 m. Most other species small in structure or shrub-like. Herbaceous flora consists of *Nepenthes*, *Sedges* and *Sphagmum*

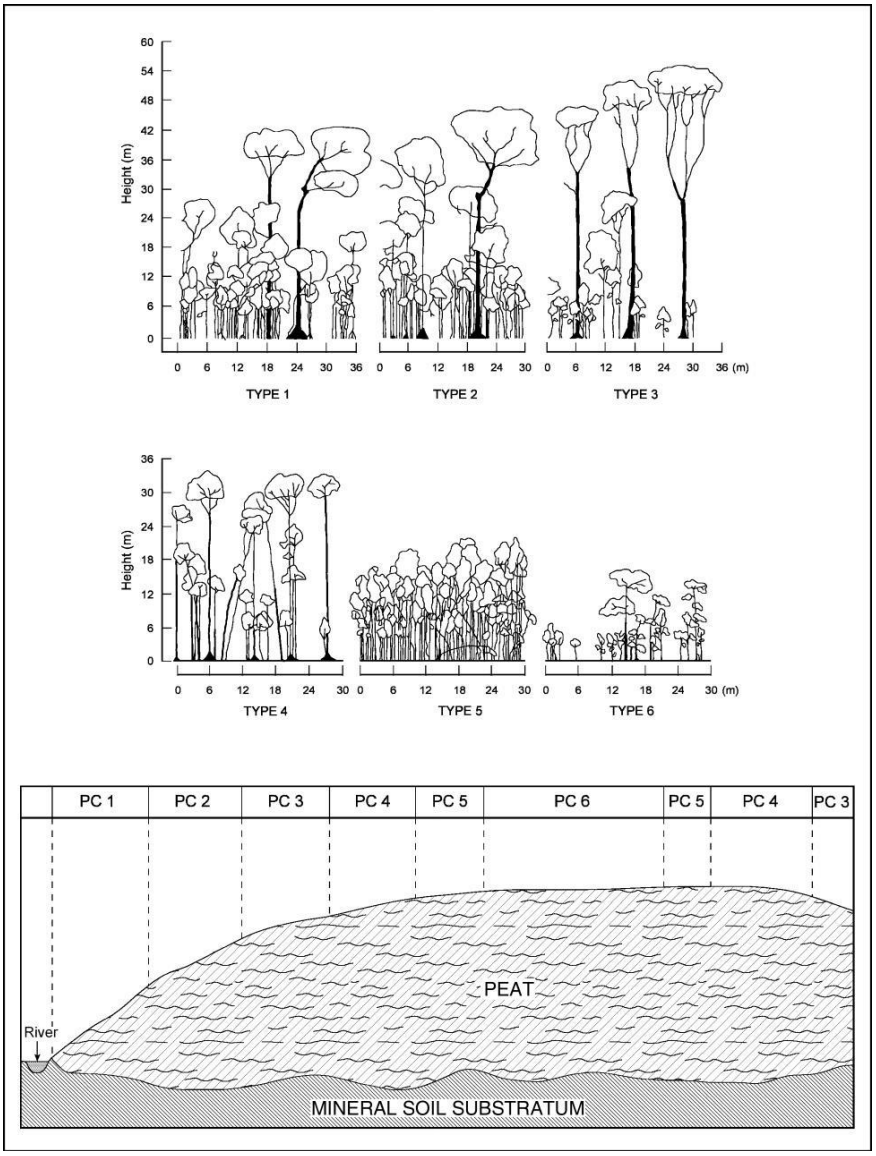


Figure 1. Overview of natural peat swamp forests vegetation zone and their position on peat dome (Source: Anderson, 1961)

A study conducted by Buwalda (1940) and Anderson (1961, 1963 and 1983) confirmed that biodiversity and biomass significantly decreases from mixed peat swamp forest (PC1) to the centre of the dome padang keruntum (PC6). According to Anderson (1961) there is much variation in the species flora and fauna composition of peat swamp forest and this is mainly related to peat depth and hydrology affecting water table depth and nutrient content (Figure 1).

2.2 Distribution of Tropical peatland

Food and Agriculture Organization (2013) reported that peat swamp forests have been estimated to cover around 358,000 km^2 worldwide. Most of it is mainly found in South-East Asia (56.6%) but also in such areas as Caribbean, Amazonia, African Continent, South China and other regions.

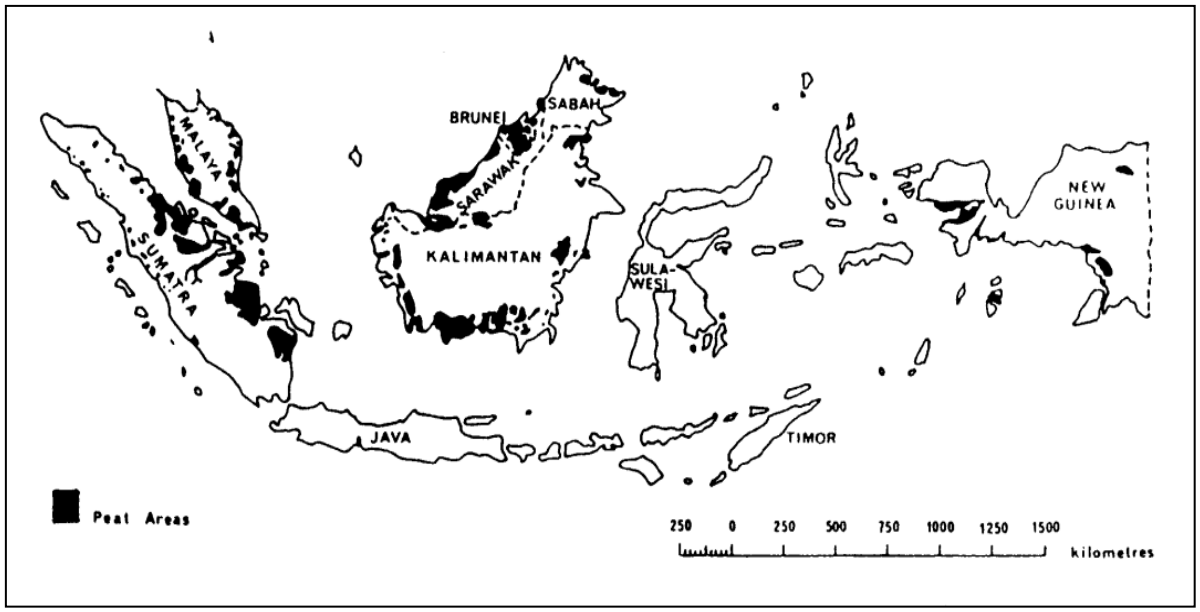


Figure 2. The map and extent of the lowland peat swamps of Borneo and surrounding area (After Andriesse, 1974; Driessen and Soepraptohardjo, 1974 and Rieley, 1992) (Source from Phillips, 1998)

Tropical peat forest is well-represented among the major forest formations of Borneo (belonging to Indonesia, Malaysia and Brunei) and also Sumatra, nevertheless there are also significant areas in the other parts of Indonesia, Malaysia, Vietnam, Thailand and the Philippines (UNDP, 2006). In Borneo, peat swamp forest occurs along the coasts of Sarawak, Brunei Darussalam, Sabah and Kalimantan on low-lying, poorly drained sites and exists further inland than its neighbouring beach forest and mangrove forest formations (Phillips, 1998). Figure 2 showed the map and extent of the lowland peat swamp of Borneo and surrounding area.

Hooijer *et al.*, (2006) estimated 12 million hectares or 45% from 27 million hectares of peat swamp forests in South-East Asia had been logged and drained. In Peninsular Malaysia, almost all of peat swamp forests have been degraded over past 50 years and by 2005 only 300, 000 hectares still remains forested with 100 ha fully protected (UNDP 2006). In Sarawak, significant areas remain, however they have mostly been degraded by logging. According to SarVision report 2011, 33.4% of the Sarawak peat swamp forest area existing in 2005 has been cleared in 2010. In Sabah, small areas of peat swamp forest remain. According to MacDicken (2001), less than 3% of the remaining peat swamp forest in Indonesia is protected forest and more than half of the original peat swamp forest in Sumatra and Kalimantan has been disturbed for development.

2.3 The diversity of flora and fauna of peat swamp forest

Tropical peat swamp forests are richly endowed with endemic flora and fauna species. The forest is characterized by their organic (histosol) soils that has developed recently, approximately within the past 5000 years and remain inadequately understood scientifically. Limited information is available on the flora and fauna (Phillips, 1998) because of the extremely difficult logistics caused by swampy conditions (Posa *et al.*, 2011; UNDP, 2006; Phillips, 1998).

Low number of animal and plant species richness and abundance in peat swamp forest (Gaither, 1994) were due to low nutrient content of ombrotrophic peats which results in a relatively low primary productivity as compared with other tropical forest formation (Bruening, 1996), poor soil characteristics (Janzen, 1974) and acidic water (Johnson, 1967). However these swamps are able to support some special adapted flora and fauna

species. Most of terrestrial fauna that are adapted to this ecosystem are confined to live above-ground on trees and canopy level (Tuen, Abang and Tawan, 2008).

Flora diversity in peat swamp forest can be divided into two; non-tree species which include climbers and herbaceous plants and tree species some of which become a food resource for animals and as timber resources for local community. The diversity of flora species in peatland is much lower compared to dipterocarp forest is due to poorer soil. Over a period of 10 years in the 1950s, Anderson (1963) has recorded 253 species of trees which include 40 small trees which rarely exceed 5-20 m height at tropical lowland peat swamp forests. In Peninsular Malaysia, a total of 132 tree species were recorded in the Bebar Forest Reserve in Pahang (Ibrahim and Ismail, 1995) and 107 tree species were recorded in the North Selangor peat swamp forest (Appanah *et al.*, 1999). In Sarawak, Anderson (1962) recorded 242 tree species in peatlands. Many of species recorded in peat swamp forests are endemic to this ecosystem for example in Peninsular Malaysia 75% of the tree found in this forest are not found in other habitat types and some have a relatively restricted distribution (Ibrahim and Ismail, 1995).

In term of fauna diversity in peatland, some studies have been carried out in Sarawak; Maludam National Park (43, 147 ha) and Loagan Bunut National Park (10, 736 ha). Maludam National Park (MNP) is the only national park in Sarawak that is made up entirely of peat swamp forest. A primate survey conducted by Bennett (1994) at Peninsular Maludam recorded a rare Red Banded Langur, endemic to Borneo and one of the most endangered primates in the world. This and the presence of other protected species such as Proboscis monkeys (*Nasalis larvatus*), Silvered Langurs, Long-Tailed Macaque, Pig-Tailed Macaque, Western Tarsiers and Slow Loris essentially led to the establishment of

the Maludam peninsular as National Park. Other terrestrial fauna surveys were conducted in Maludam National Park in conjunction with the joint Malaysian-Netherlands project (2000-2004) by Gumal *et al*. (2004), Hon and Gumal (2004) and Mohd Azlan (2004). Two crocodiles and six species of amphibians were reported by Lading and Paschal (2003). A survey of fish fauna by Lee and Bali (2003) recorded 28 species from 11 families. Rahim *et al.* (2009) studied the fish fauna in black water and waters originating from peat swamp forests at Batang Kerang, Balai Ringin Sarawak and reported 12 species of fish from 12 families and Kissing Gourami fish was the dominant species.

2.4 Avifauna studies at peat swamp forest versus other forest types

A study conducted by Gaither (1994) in Indonesia showed that peat swamp forest supported a reduced understory avifauna community relative to lowland dipterocarp forest. Despite this peat swamp forest appear important in the ecology of Southeast Asian avian communities because they support specialized species and attract frugivores birds at sporadic intervals and are important habitats for endangered species, hornbills (Bennet 1994; Melvin *et al.*, 2004) and waterbirds (Sebastian, 2005).

According to Sebastian (2002), a total of 237 species of birds have been recorded from Malaysian peat swamp forests and 27% of the birds are on the IUCN red list of globally threatened species. Previous studies on birds at Maludam National Park, Sarawak by Bennett (1994) provided a list of 22 species which include four species of hornbills, three species of kingfisher and the Green Imperial Pigeon all of which are protected under the Wild Life Protection Ordinance, 1998. A more recent survey Beintema and Sim 2004, recorded 166 species of birds in August 2004 adding to an earlier report by Bennett (1994).

In North Selangor peat swamp forest, a total of 173 species of birds including 145 breeding residents and 21 non-breeding migrants were recorded (Prentice and Aikanathan, 1989).

In Logan Bunut National Park in northeast Sarawak, bird diversity in peat swamp forest was significantly different from fruit orchard and mixed dipterocarp forest where peat swamp forest (18 species) was the less diversified site in term of bird richness as compared to fruit orchard (19 species) and mixed dipterocarp forest (20 species) through mist-netting method (Laman *et al.*, 2006). Using mist-netting technique Rahman and Tuen (2006) captured 679 birds representing 67 species from 25 families in a peat swamp forest patch located next to UNIMAS campus in Samarahan from 1996 to 1999. It was concluded that the bird abundance and diversity is poor compared to other non-peat swamp sites. This was attributed to the less number of fruit trees in peat swamp forest and high tannin content of most leaves that makes them unpalatable (Laman *et al.*, 2006).

2.5 Effect of agriculture development (oil palm plantation, paddy and sago) on avifauna diversity

There are studies comparing the effects of oil palm plantation and other agriculture development on avifauna (Peh *et al.*, 2005; Peh *et al.*, 2006; Azman *et al.*, 2011; Jambari *et al.*, 2012) were conducted. There is very little data on bird diversity at oil palm plantation on peatland ecosystem as compared to mineral soil (Amit *et al.*, 2011). Studies by Chennon and Susanto (2005) and Koh (2008) revealed that oil palm can support a reasonable avifauna community especially those that prey on insects found local vegetation such as ground and epiphytic ferns (e.g., *Nephrolepsis biserrata*) in oil palm plantation, provides nesting sites for several birds such as Yellow-vented Bulbul, Rufous-tailed Tailorbird (*Orthotomus sericeus*) and Yellow-bellied Prinia (*Prinia flaviventris*). These

epiphytes make the plantation hospitable for birds and help maintain the natural pest control services hence reduce the need for traditional chemical methods. Besides that, the presence of epiphytes on palm trees and amount of ground vegetation cover suggest positive effects on the diversity of birds in oil palm plantation (Koh, 2008).

Several studies on bird diversity in oil palm plantation ecosystems have been carried out to figure out what species of bird used this habitat to continue their survival (Chennon and Susanto 2006; Amit *et al.*, 2011; Cagod and Nuneza 2012; Jambari *et al.*, 2012; Gervais *et al.*, 2012). Amit, *et al*. (2011) carried out a study at Durafarm Oil Palm Plantation, Betong Sarawak which was planted on peatland. Through bird observation and mist-netting method, a total of 474 individuals of birds belonging to 44 species were recorded. According to this study, 30% of the total birds recorded in oil palm plantation are categorized as protected species under the Sarawak Wild Life Protection Ordinance (1998) and this result suggests that the oil palm plantation in Betong has a reasonably good community of birds. Yellow-vented Bulbul (Merbah Kapur) was the dominant species found in DFM comprising 23.3% from the total individuals recorded and this result is similar to that of Azman, *et al.* (2011). Azman, *et al.* (2011) stated that Yellow-vented Bulbul are usually seen hunting for insects within shrub areas. There is little study on why this species become dominant species in oil palm plantation and whether this species can become biological control or pest to oil palm plantation industry.

The dominance of Yellow-vented Bulbul in certain community is probably due to their wide ranging diet of both plants and animals (Tan and Ria, 2001). They are well-known as frugivores and insectivores birds in regions of the Old World such as the Malaysian lowland rain forest (Symthies, 1999). They are fond of berries and small fruits, especially

figs and cinnamon tree fruits and sip nectar, nibble on young shoots and snack on insects (Ward, 1969; Fishpool and Tobias, 2005; Wells, 2007 and Wee, 2009). They forage in bushes and trees for berries and insects and may even catch swarming insect on the wing. Yellow-vented Bulbul is solitary and feed alone or in pairs, although fruiting trees may attract a flock of them. But they roost in small communities in dense bushes or trees (Tan, 2001).

A study of the influence of agricultural system, stand structural complexity and landscape on foraging birds in oil palm landscapes was carried out by Azhar *et al.* (2013) on the west of Peninsular Malaysia. Bird survey was carried out at oil palm plantation which divided into two; plantation estates and smallholdings and logged-over peat swamp forest. A total of 194, 108 and 55 bird species were recorded in logged-over peat swamp forest, plantation estates and smallholdings, respectively. From this study, lower abundance of insectivorous, granivorous and omnivorous in oil palm plantation compared to logged-over peat swamp forest because of extensive timber extraction. Besides that, raptors and wetland taxa was higher recorded in oil palm plantation than logged-over peat swamp forest while frugivorous species was more abundant in smallholding compared to estate due to presence of native tree. Other than that, only arboreal omnivores and terrestrial frugivores were affected by the closeness of nearby natural forest. In this study, stand age of oil palm plantation, canopy cover and habitat complexity were factors that related to bird foraging guild diversity in oil palm.

Chenon and Susanto (2006) have carried out an inventory of birds in two plantations with three different planting years: in Bah Jambi (174 ha), 2000, 1995, and 1975 and in Bukit Maradja (194 ha), 2001, 1998, and 1985. According to this study, 29 species of bird have

been observed in both oil palm plantations. According to this study, bird dominance varies according to plantations: *Pycnonotus goiavier* from 24.4 to 28.7% of all individual birds, *Prinia* spp. from 27.6 to 34.4%, *Parus major* from 9.5 to 10.6%, *Copsychus saularis* from 4.5 to 8.6%, and *Halcyon smyrnensis* from 5.1 to 6.9%. This study found that *Parus* can be found on higher palms, *Copsychus* and *Prinia* more common on younger planting, Bulbuls on both older and younger palms, as well as others such as *Centropus bengalesis* only at the level of the lower strata among the cover. From this study, many species are present from soon after planting up to mature oil palm but this statement is contrary to Koh, (2008) who stated that age (range from 2-29 years old) did not influence species richness of birds in oil palm landscapes.

Cagod and Nuneza (2012) also carried out bird study in oil palm plantation with different age of palms at Agusan Del Sur and Compostela Valley, Philippines. Through line transect, mist-netting and birdwatching methods, a total of 88 species of bird include 31 endemic species were recorded. Species richness, abundance and number of endemic species were higher in mature plantation than in young plantations. The presence of vulnerable species in this site suggests the need to protect the degraded secondary residual forest and forest patches along the plantation.

A study of bird in oil palm plantation also was carried out by Gervais *et al.* (2012) at Bintulu, Sarawak through observation method. This study suggested that there is positive correlation between numbers of birds and proximity to secondary forest. The presence of riparian buffer zone in the plantation had a positive effect on bird diversity. Their results showed that bird diversity and abundance were slightly greater at sites with nearby forest

fragments or buffer zones along streams or rivers compared to sites that located more than 1000 m from forest fragments or buffer zones along streams or rivers.

A study on relationship between bird species richness and different regimes (plantation vs. smallholdings) and vegetation characteristics in Selangor, Perak, Negeri Sembilan and Pahang have been carried out by Jambari *et al.* (2012). From their observation data, a total of 72 species of birds have been recorded in this study. Their finding show that, plantation and smallholdings can support similar total number of bird species richness, however they found that greater height of the ground vegetation cover had a positive effect on the total species richness of bird in oil palm plantation. Hence, from this study it show that increase height of ground vegetation, the species richness of bird is increase.

Several studies on bird diversity compared oil palm plantation with other crops and different types of forests (Peh *et al.* 2005; Peh *et al.*, 2006; Tuen *et al.*, 2006; Gouk 2009; Azhar *et al.*, 2011; Azman, *et al.*, 2011). Observation of birds was conducted by Azhar *et al.* (2011) at different management regimes in oil palm landscapes which include 41 plantation estates, 14 smallholdings and 20 sites in an extensively logged peat swamp forest, West Coast Peninsular Malaysia (Perak, Selangor and Negeri Sembilan). The results showed that logged peat swamp forest (194 species) recorded the highest number of birds species followed by plantation estates (108 species) and smallholdings (55 species). Azhar *et al.* (2011) concluded that plantation estates and small holdings supported similar bird assemblages but the latter supported significantly more species. This study also highlighted the reduced species richness in oil palm landscapes but high abundance of some individual bird species in specific types of stands including some forest, migratory and wetland species.

Azman, *et al.*, (2011) had carried out a study in three different habitats (secondary forest versus monoculture (oil palm plantation and paddy field)) in riparian areas of the Kerian River Basin, Perak. Through point-count observation and mist-netting method, a total of 132 species of birds from 46 families were recorded. Their study reveals that the conversion of forest to either oil palm plantation or paddy fields showed a decline in bird diversity and changes in the distribution of bird feeding guilds. Other than that, vegetation diversity and the habitat structure influence the number of bird species occurring in an area. Besides that, carnivore, granivore and omnivore guilds of birds were higher in the plantation as compared with secondary forest with higher of insectivore, insectivore-frugivore and frugivore guilds of bird.

Peh *et al.* (2005, 2006) studied bird species in rubber tree plantation, oil palm plantation and logged forest versus primary forest in southern Peninsular Malaysia using point count method. The result showed that, primary forest recorded 139 species of bird followed by logged forest with 114 species, rubber plantation with 22 species and oil palm plantation with 16 species. Hence, among the agricultural land uses, rubber tree plantations had the highest species richness and abundance as compared to oil palm plantation.

A study done by Tuen *et al*., (2006) through mist-netting method at Bratak Oil Palm Plantation, Bau, Sarawak in 2005 recorded a total of 73 birds representing 26 species with 20 species in the adjacent forest compared to 11 species in plantation area. However same study were conducted by Gouk (2009) at the same site using similar effort recorded a total of 78 individuals representing 28 species with 17 species in adjacent forest and 8 in plantation. This result suggests some species may have disappeared from the site between 2005 and 2009. According to Gouk (2009) high number of species of insectivorous-

frugivorous birds was recorded with Olive-winged Bulbul being the dominant species. It was concluded that the changes in microclimate, structure and food distribution and abundance in oil palm plantation are factors that influence the diversity, distribution and abundance of birds.

2.6 Feeding guilds of bird in oil palm plantation and peat swamp forest

Feeding guild reflects the types of food that is available in that habitat (Blake 1983). According to Pearman (2002), the variation in the vegetation structures is one of the factors that influence the distribution of bird feeding guilds. Several studies have been carried out to investigate the feeding guild of bird in oil palm plantation compared to forest and other crops (Gouk, 2009; Azman *et al*., 2011; Azhar *et al*., 2013). All of these studies showed that oil palm plantation supported fewer feeding guilds compared to forest and other crops due to greater complexity in the structure of forest and other crops.

In oil palm plantation, omnivorous and granivorous birds rely on ground-layer vegetation cover and undergrowth height for feed sources and protection from prey. The presence of of carnivores in this habitat was influenced by the availability of their prey such as rats and snakes (Louren and Sergio, 2006). According to Azman *et al*. (2011), occurrence in oil palm plantation of omnivorous bird species such as Yellow-vented Bulbul, Jungle Myna and Common Myna are due to their wide dietary range that allows them to adapt to this habitat. Azman *et al*. (2011) also reported less number of insectivore, insectivore-frugivore and frugivore bird species in oil palm plantation compared to forest.

A total of nine guilds of birds have been recorded by Gaither (1994): litter-gleaning insectivore, shrub foliage-gleaning insectivore, tree foliage-gleaning insectivore, bark-

gleaning insectivore, flycatching insectivore, insectivore-nectarivore and insectivore-frugivore. Insectivore-frugivore bird species was the diverse species in peat swamp forest. Litter-gleaning insectivores, tree foliage-gleaning insectivores and barking-gleaning insectivores were significantly lower numbers in peat swamp forest compared to the dipterocarp forest. Increase in the number of frugivorous birds in peat swamp forest especially in June was due to the presence of large fruit of *Callocarpa* sp.

2.7 Use of understorey bird diversity as biological indicator

In biotic communities, each group has different responds, however not necessarily independently, to disturbance and it is difficult to infer community state from only one. Birds are regarded as the best indicator for habitat quality and general faunal health (Furness and Greenwood, 1993) because they are particularly sensitive to changes in habitat (understory) and habitat fragmentation (Furness and Greenwood, 1993; Barlow *et al.*, 2006) and they represent a number of niches in several trophic levels and by their diverse requirements, are good indicators of habitat quality. Besides that, they are often present in high numbers, relatively visible and identifiable (Bibby *et al.*, 2000; Furness and Greenwood 1993). Understory bird is one group of birds which are known to be highly sensitive to habitat disturbance such as forest fragments (Vergara and Simonetti, 2006), logged rainforest (Aleixo, 1999), fire-disturbed forest (Barlow *et al.*, 2006) and forest edges bordering agricultural fields (Restrepo and Gomez, 1998) and road clearings (Laurance, 2004) and have been frequently used as biological indicator in other studies (Gaither, 1994; Wunderle *et al.*, 2006). Understory birds are vulnerable to habitat fragmentation because of the reduction in habitat quality and bird movement (Vergara and Simonetti, 2006).

Mist-net is a widely used technique for capturing birds to monitor avian populations (MacArthur and MacArthur, 1974; Silkey, 1999; Dunn and Ralph, 2004; Spotswood *et al.*, 2012). By using this technique, the average rate of captured bird experience injury incident was 0.59% while mortality incident was 0.23% and the bird captured was less at risk to this incident therefore there is no evidence for increased mortality over time of injured compared with uninjured birds (Spotswood *et al.*, 2012). This technique is commonly used in studies of tropical understory bird communities (Wong, 1986; Levey, 1988; Loiselle and Blake, 1991; Gaither, 1994; Laurance, 2004). Mist-nets were used at ground level to census birds. This method provides the most efficient and reliable estimates of relative density and ranging movements of birds in tropical-forest understory (Okia, 1976; Greig Smith, 1980; Karr, 1979). However, species richness obtained using mist-net are lower as compared with birds recorded through observation because it is restricted to birds that use the understory between 0.2 to 3 m above the ground level (Rahman and Tuen, 2006). The nets are normally operated for 12 hrs (Rahman, 2002; Zakaria *et al.*, 2005; Laman *et al.*, 2006; Zakaria and Rajpar, 2010).

2.8 Oil Palm Development on Peatland Ecosystem

Oil palm is one of the world's most rapidly expanding crops in Southeast Asia. Driven by plans to generate economic profits, oil palm plantation expands rapidly in Southeast Asia except Singapore. It is the main industrial and economic crop in Malaysia and Indonesia and both countries are the two largest oil palm-producing in the world (Koh *et al.*, 2011; Haron and Chan, 2009; Basiron, *et al.*, 2004).

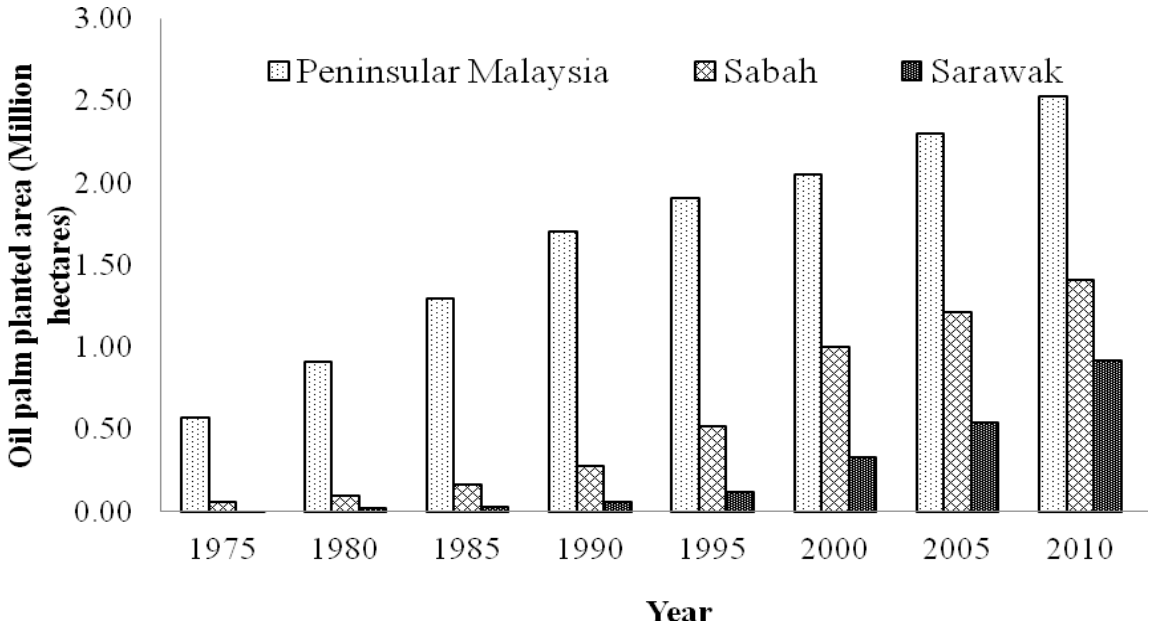


Figure 3. Oil palm planted area in Peninsular Malaysia, Sabah and Sarawak from 1975-2012 (Source: Malaysian Palm Oil Board, 2013)

Figure 3 showed the total planted area for oil palm crop in Peninsular Malaysia, Sabah and Sarawak from 1975 to 2012. The graph showed that oil palm development in Malaysia was drastically increased over years and become one of the economic backbones in this country. According to report from Economics and Industry Development division from MPOB in 2012, there are about 5.08 million hectares of oil palm planted in Malaysia and mostly located in Peninsular Malaysia (50.4%), followed by Sabah (28.3%) and Sarawak (21.3%). Oil palm industry accounts for 5-6% of Malaysia's Gross Domestic Product (GDP), and the importance of the industry to the country's export earnings is very significant. According to Ministry of Plantation Industries and Commodities Malaysia, in 2011, the export earnings from palm oil export was RM 80.30 billion which is an increase of RM 20.51 billion from previous year. The percentage of palm contribution in the overall export value in 2011 was 61.8% as compared with previous year 52.8%.

In Malaysia, oil palm was first commercially planted in year 1917 at Tennamaran Estate, Selangor by Frenchmen, Henri Fauconnier to replace rubber plantation (Corley and Tinker, 2003). As the land become scarce, the expansions move to Sabah and Sarawak (Fitzherbert, *et al.,* 2008). Peat was considered as problem soil because its physical and chemical properties make the cultivation of many agricultural crops difficult (Andriesse, 1988) but still, there have also been at least short-term successes with tree crops, such as sago and oil palm. However, due to high demand on oil palm products every year, the total oil palm planted area increase continuously. During the early years of its expansion, most of the oil palm was planted on suitable mineral soil and as available suitable land is diminishing, some of the oil palm is now being planted on marginal soils such as peat soil (Omar *et al.,* 2009). The expansion of plantation crops such as rubber followed by oil palm in the early 1960's on these problem soils again has limited success due to the use of large drains to remove excess water (Paramananthan, 1998). However, excellent work conducted by United Plantations to solve this problem in 1986 by introducing water control and nutritional management, significantly increase the successful cultivation of oil palms on peat (Gurmit *et al.,* 1986). Hence, finding from this work resulted in a rush to develop large areas of peat lands to oil palms in the 15 year particularly in Indonesia and Malaysia.

Through digitization of soil maps of Peninsula Malaysia, Sabah and Sarawak, Omar *et al.* (2009) reported that the area of peatland in Malaysia totals 2.43 million hectares. From this study, Sarawak (1.59 mil ha) has the largest areas of peatland followed by Peninsula Malaysia (0.72 mil ha) and Sabah (0.12 mil ha). In 2009, Sarawak has the largest area of oil palm cultivation on the peat (437174 ha) followed by Peninsula Malaysia (207 458 ha) and Sabah (21 405 ha).

Government and non-government agencies from developed countries have expressed great concern regarding the conversion of huge lands to oil palm plantation. Recently, oil palm planted on peat ecosystem became hot issues in the world due to development and disturbance of the peatlands which can change the natural ecological balance. Many campaigns and criticisms have been raised by the environmentalist (Centre for Science in the public interest, 2005; Friends of the Earth Trust, 2007; Greenpeace, 2007; Mongabay, 2012) on issues such as decrease in biodiversity and loss of above ground biomass due to conversion of forest to oil palm plantation. Hence, establishment of the Roundtable for Sustainable Palm Oil (RSPO) was formed to regulate practice and encourage sustainability in oil palm plantations through a set of Principles and Criteria and one of the guideline required was oil palm plantation should maintain healthy biodiversity. Therefore it is important to monitor impacts and make efforts to protect the ecosystem, restoring balance and maintaining the ecosystems function and services.

Even though there is a need to develop land for oil palm industry, sustaining the environment and biodiversity has become a major component in all aspects of the Malaysian oil palm industry. The resilience and growth of the oil palm industry in Malaysia is due to the Government's strategic approach in developing agriculture land in a sustainable manner by enhancing productivity and the same time mitigating the impact on the environment and biodiversity (Haron and Chan, 2009). Malaysia government has to come up with various researches that relates to the direct impact of conversion of forest to oil palm plantation on biodiversity globally. Such evidence can only be obtained through systematic research on the effect of land conversion into oil palm plantation on fauna diversity and the process that maintain this diversity. All this information will provide new sights into how to preserve and enhance fauna diversity on oil palm plantation.

CHAPTER 3

MATERIALS AND METHODS

3.1 Location of sampling sites

Two sites in Betong Division, Sarawak were selected for this study (Figure 4). The first site was an oil palm plantation on peat land (DFM) and the second site was secondary peat swamp forest (CMC) at Betong, Sarawak.

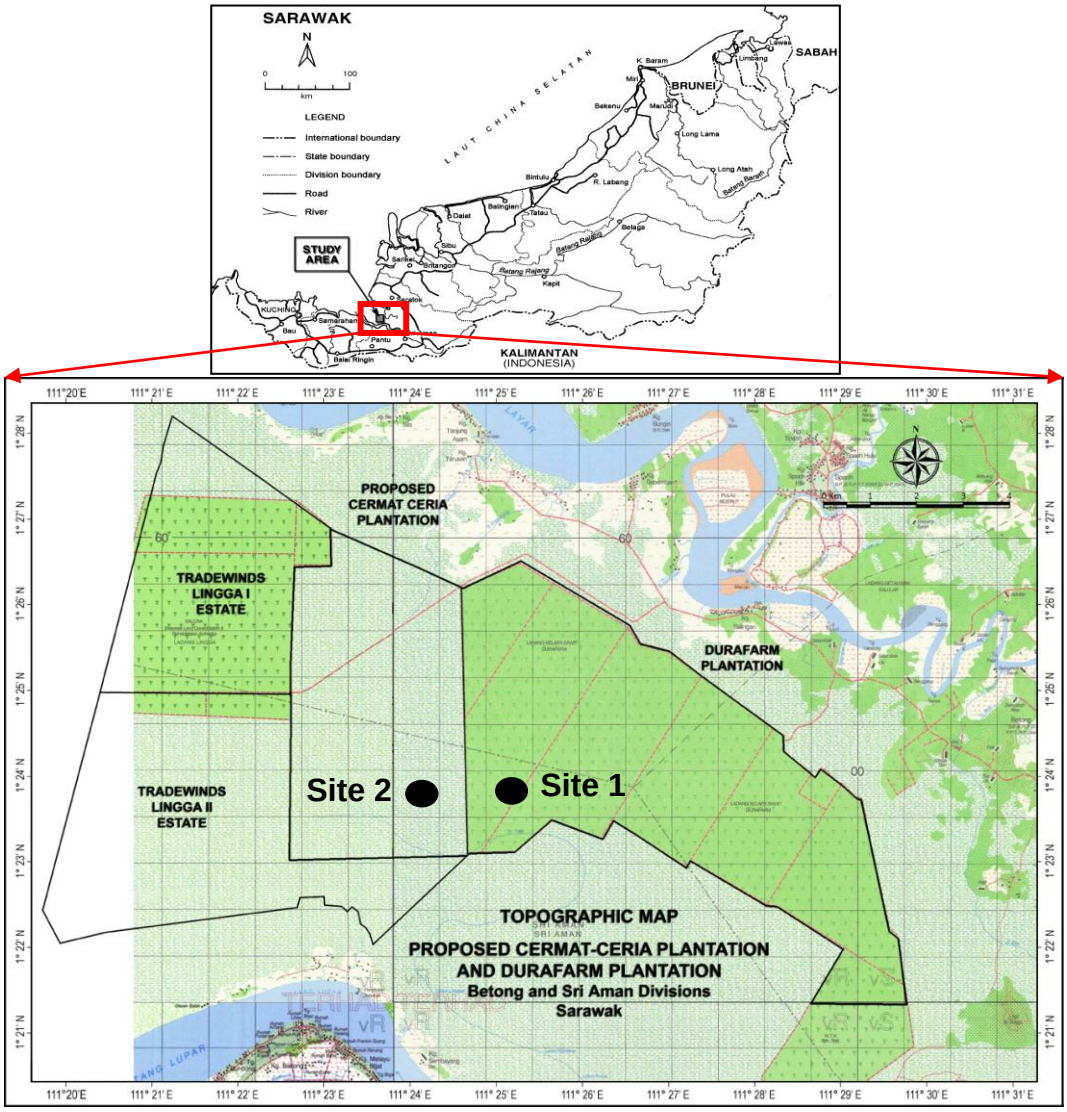


Figure 4. Location of sampling sites at DFM (Site 1) and CMC (Site 2) (Source: Paramananthan 2012)

Both sites are located between the Batang Lupar in the south and west and the Batang Layar to the north. These sites were separated by 3 m wide perimeter drain with 2 m depth constructed by DFM management to control water level inside the plantation (Figure 5) and the distance from forest to neighbouring oil palm is 20 m. A drainage canal delineates the boundary between these two sites.

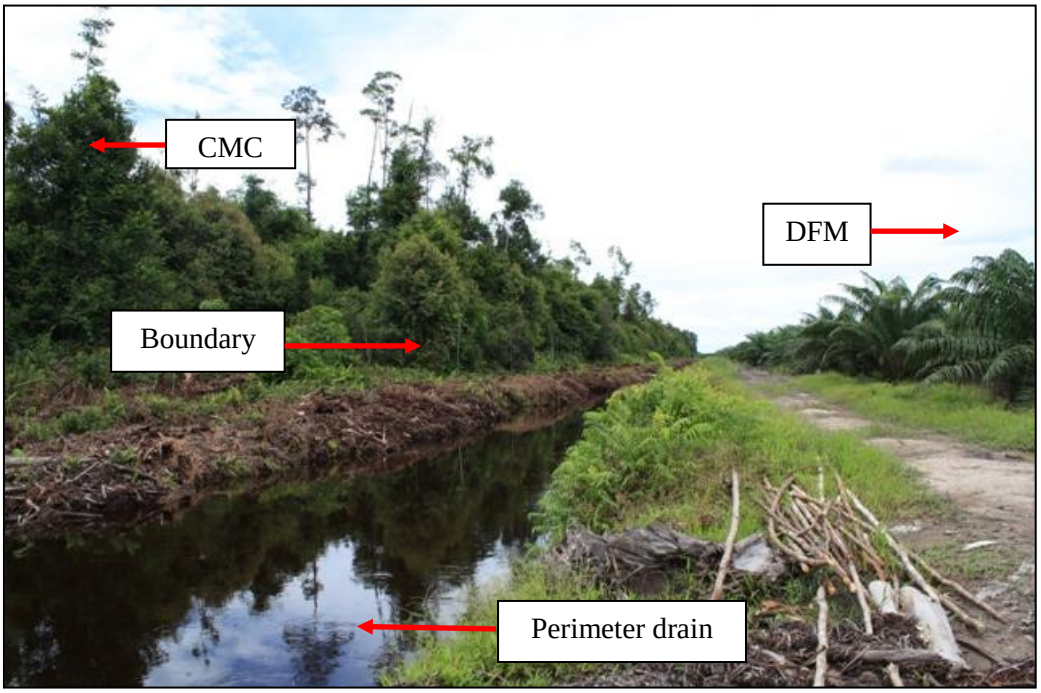


Figure 5. Perimeter drain constructed by DFM to control water level in plantation act as a boundary site.

3.1.1 Durafarm Oil Palm Plantation (DFM)

The DFM belongs to WTK Sdn. Bhd. and has been planted with oil palm, now aged seven to 13 years old. It has an area of about 5, 022 ha and located approximately 35 km from Betong Town. The sampling site was located at block 88 (Figure 6) which was planted with oil palm since 2004. The picture shows the growth of the same palm tree at block 88 in DFM in 2011 and 2013 with palm height 4 to 5 m. The palm height has increased and the palm fronds become broad.

Figure 6. Photographs showing growth comparison of the same oil palm tree at block 88 in DFM from 2011 to 213. Note the presence of weeds between the rows of oil palm

The above ground vegetation of oil palm plantation comprised of common weeds such as broad sword fern (*Nephrolepis biserrata*), gaint fern (*Stenochaena palustris*), buffalo grass (*Paspalum conjugatum*), lawn grass (*Axonopus compressus*), senduduk (*Melastoma malabathricum*) and lesser fimbristylis (*Fimbristylis milliacae*). Normally, these weeds will be removed or treated using herbicide to control their growth around the oil palm tree because they compete for nutrient with the oil palm trees hence influence its yield. However in this plantation, the oil palm management do not remove all the weeds so fauna diversity is expected to be higher compared to a "clean" plantation. These weeds play an important role for fauna nesting habitat, food resources and security (hide from predator). Fruit harvesting were carried out twice or three times a month depending on oil palm growth. The peat swamp forest community for this site was previously Alan Batu forest (Anderson, 1963) before converted to oil palm plantation. The peat soil comprised highly decomposed sapric organic materials with undecomposed wood in the upper 100 cm and often undecomposed fibric organic soil materials with some pieces of wood below 100 cm

depths. These soils are underlained by non-sulfidic marine clays at depths of 150-300 cm depending on the depth phase (Paramananthan, 2012).

3.1.2 Cermat Ceria Forest (CMC)

Cermat Ceria Peat Swamp Forest (Figure 7) comprised 2,477 ha of degraded forest located adjacent to DFM and also located between DFM and Lingga1 Estate which belongs to Tradewinds Plantation Bhd. It was last logged was about 20 years ago. The land has been allocated to Sarawak Plantation Bhd. and will be cleared for oil palm plantation soon.

The sampling site was located at Padang Paya Forest (PC5) with canopy height between 15-20 m where the nets were set up at two points. The canopy and structure of the forest are even. This forest is characterised by dense stands of pole-size trees (Sarawak Forestry Department). The most dominant species of trees were *Lithocarpus dasystachyus* (Empenit Padang) and *Cephalomappa paludicola* (Arau Paya). Forest Research Institute Malaysia (2011) reported that, a total of 55 species of trees found in CMC.

Figure 7. Photographs showing the adjacent peat swamp forest (CMC) showing mist-nets being set up using telescopic aluminium pole (foreground right)

3.2 Field Sampling

3.2.1 Mist-netting Method

Fifteen mist-nets of 36 mm mesh-size and measures 9 x 2.5 m with three shelves were used in DFM and CMC to capture understorey birds. The nets were set up at two points for each site. The nets were set up 200 m and 500 m away from the boundary area. The net placement at 200 m from the boundary was designed to avoid edge effect. Previous researchers have shown that the maximum distance for edge effect is less than 200 meters into the forest (Rosli and Zakaria, 2011; Zakaria *et al.*, 2013; Moradi *et al.* 2009; Wilcove *at al.* 1986; Paton 1992). Sampling at the 200 m site was carried out in February, May, July and November 2011 and January 2012 while sampling at the 500 m site was done in May, July and November 2012 and February and May 2013. The mist-nets were activated in the morning at 0600 hours until 1800 hours in the evening for three days and were checked every two hours. Captured birds were identified, tagged and released at the boundary area between both sites. Species identification was based on Myers (2009) and these birds were further categorized to forest bird and garden bird based on Malaysian Nature Society (2013).

3.2.2 Distribution of food resources

Transect survey for insect and fruit was carried out by walking along 150 m trail at DFM and CMC. This survey was carried out during the same sampling day. All the insects and fruits available along the trail were recorded. Identification for insects was done to order level only. Species of fruit found along the trail that cannot be identified on site were collected and brought to UNIMAS laboratory for further identification.

3.2.3 Study on diurnal movement pattern of birds

Fifteen mist-nets were set up parallel to the boundary to determine the direction and frequency of bird crossing between the two ecosystems (oil palm plantation and adjacent forest). The data from where the bird hit the net and what time the bird was captured were recorded. The mist-nets were activated at 0600 hr until 1800 hr (Rahman *et al.*, 1998, Rahman and Tuen, 2006). Boundary data were used to study the movement of birds between oil palm plantation and logged-over forest according to three different time period. This period was divided into three due to in early morning (0600-0959 hr), midday (1000-1559) hr and late afternoon (1600-1800 hr).

3.2.4 Collection of stomach content of Yellow-vented Bulbul

Forty five individuals of this species were sacrificed for stomach content analysis (permit approved by Forestry Department of Sarawak – refer to Appendix 1). The stomach of this bird was open on the site and the content washed using distilled water and preserved into a vial containing 70% of ethanol for laboratory analysis (Seefelt and Gillingham 2006; Durães and Marini, 2005). The samples were transported to a laboratory in Universiti Malaysia Sarawak for further analysis.

3.3 Laboratory technique

3.3.1 Analysis of Stomach Content

The stomach samples were analysed in the Universiti Malaysia Sarawak laboratory. The stomach content was put in a petri dish and examined it under microscope. Stomach contents were classified into insect part and others such as plant, anthropod, and parasite. The insect and other prey items present in the stomach was examined under microscope identified until order level. The insect parts were identified based on Borror *et al*. (1954)

and Triplehorn and Johnson (2005). The insect parts detected were head, mouthparts, elytra, mandibles, body structure, legs and wings. A compound microscope (Motic®SMZ-168 Stereo Zoom Microscope) with a camera attached was used. The images were taken by using Motic Image Plus Version 2.0 software with resolution of 1600 x 1200 pixels and the magnification lens were adjusted between the range of 2.0 – 7.5. Identifiable insect parts were also photographed. The identified insect and plant parts were recorded according to their order.

3.4 Data Analysis

3.4.1 Shannon Index

The Shannon Index (*H*') was used to indicate the species diversity of birds at two different study areas - oil palm plantation and adjacent peat swamp forest. This index was also calculated for sampling sites at located at different distance from boundary. This index was calculated using the natural log function according to the following equation:-

Shannon formula,

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

Where H′ = Shannon index

p_i = the proportion of individuals found in the *i*th sample

ln = natural log

3.4.2 Margalef's Index

Margalef's Index was used to estimate species richness of birds in all sampling sites. It was calculated from the total number of species present and total number of individuals. This index is independent of the number of individuals in the sample only if the relationship between (S-1) and ln (N) is linear.

Margalef's formula,

$$R_1 = (S - 1) / \ln (N)$$

Where R_1 = Margalef's Index

S = number of species

N = total number of individuals

ln = natural log

3.4.3 Pielou's Index

Pielou's Index was used to estimate species evenness of birds in all sampling sites. Evenness is a measure of the distribution of individuals among the species. This index is the ratio of observed diversity to the maximum possible diversity of a community with the same species richness.

Pielou's Formula,

$$E = \frac{H'}{\ln S}$$

Where E = Pielou's Index

H'= Species diversity

S= number of species

ln = natural log

3.4.4 Zar t-test

Zar's Modified t-test (1996) was used to test for difference in Shannon diversity indices between oil palm plantation and adjacent peat swamp forest and at different distance from boundary site.

Zar's t-test formula,

$$t = \frac{H_1' - H_2'}{s_{H_1' - H_2'}}$$

3.4.5 Chi-squared Test

Chi-squared (χ^2) test also was used to test whether the differences in the frequency and direction individuals of birds hitting the net from plantation side or forest side at different time of day was significant or not.

Chi-squared χ^2 distribution formula,

$$\chi^2_{\text{Obs}} = \sum \frac{(O - E)^2}{E}$$

Where O = Observed value

E = Expected value

3.4.6 Ivlev's Electivity Index

Ivelev's electivity index was used to measure the degree of food selection by the dominant species, Yellow-vented Bulbul in oil palm plantation toward a particular prey species. It is commonly used to compare the feeding habits of predator with the availability of potential food resources in the natural habitats (Strauss, 1979). The relationship is defined as

$$E = \frac{r_i - p_i}{r_i + p_i},$$

where E = electivity

r_i = relative abundance of prey item i in the gut (as a proportion or percentage of the total gut contents)

p_i = relative abundance of the same prey item in the environment.

The possible range of the index is -1 to +1. The negative values indicate avoidance or inaccessibility of the prey item, zero indicates random selection from the environment and positive values indicate active selection (Strauss, 1979).

CHAPTER 4

RESULTS

4.1 Comparing bird community at DFM and CMC

The overall results showed that a total of 334 birds representing 48 species were mist-netted throughout this study (Table 2) and this represents approximately 7.6% of the total species known to occur in Borneo. Seven species protected under Sarawak Wild Life Protection Ordinance, 1998 (SWLPO, 1998) were recorded in this study. Seven species were listed as Near Threatened and two as Vulnerable under the International Union for Conservation of Nature (IUCN) Red List Threatened Species (2013). The bird community was dominated by Yellow-vented Bulbul which accounted for 16.8% of the total bird caught in this study and not a single individual of this species was caught in adjacent peat swamp forest. The result showed that CMC has 31 species while DFM has 30 species indicating similarity in the number of species between the two ecosystems.

The bird community in oil palm plantation on peat is made up of 18 families representing 30 species and 184 individuals. Three species of birds (two kingfishers and one woodpecker) are categorized as protected animal under Schedule 1 of SWLPO, 1998. In term of the status under the IUCN Red List of Threatened Species (2013), a total of three Near Threatened species were recorded. The family Timaliidae (babblers) and Pycnonotidae (bulbuls) are the most diverse with four species each, followed by Nectariniidae (sunbirds and little spiderhunters) and Cisticolidae (tailorbirds and prinias) with three species each. The rarest families were the Estrildidae, Accipitridae, Dicaeidae, Columbidae and Sturnidae with only single individual each. The most abundant species is *P. goiavier* which accounted for 30.4% of the total birds caught at this site.

A total of 150 birds representing 15 families and 31 species were mist-netted at CMC. The family Timaliidae (babblers) is the most diverse with nine species, followed by Nectariniidae (sunbirds and little spiderhunter) with four species and Alcedinidae (kingfishers) and Picidae (woodpeckers) with three species each. The families Strigidae, Cisticolidae, Camprimulgidae and Rhipiduridae were the rarest, with only one bird caught for each species. The most abundant species is Black-throated Babbler (*Stachyris nigricollis*), accounting for 15.3% of the total of birds caught at this site, followed by Chestnut-winged Babbler (11.3%), Fluffy-backed Tit Babbler (9.3%), and Short-tailed Babbler (6.0%). Seven species of birds (three kingfishers, three woodpeckers and a single species of owl) recorded in this site are listed under protected animal by schedule 1 of SWLPO 1998. Five species are listed as Near Threatened and two as Vulnerable according to IUCN Red List 2013. Hence, CMC has higher conservation value for bird as compared with DFM.

Various indices were computed to indicate the richness, eveness and diversity of the bird community in CMC and DFM. The Margalef's Index of species richness (R_1) was 5.987 for CMC and 5.561 for DFM, indicating that both sites are similar in richness. Pielou's Index of species eveness (E) indicate that the distribution of individuals among species was uneven at both sites where species of bird in CMC (E=0.880) is more even compared to DFM (E=0.763). Shannon diversity index (*H'*) indicates that species diversity of understorey bird was significantly higher in CMC compared to DFM (4.360 vs 3.745, $p<0.05$).

Table 2. Summary of total species, individuals (N) and relative abundance (RA) of captured birds in DFM and CMC, Betong, Sarawak

Family Local Name (*Scientific name*)	IUCN Status	(Oil palm) DFM		(Forest) CMC	
		N	RA, %	N	RA %
Nectarinidae					
Purple-naped Sunbird (*Hypogramma hypogrammicum*)	LC	0	0.00	4	2.67
Ruby-cheeked Sunbird (*Anthreptes singalensis*)	LC	4	2.17	6	4.00
Brown-throated Sunbird (*Anthreptes malacensis*)	LC	2	1.09	0	0.00
Crimson Sunbird (*Aethopyga siparaja*)	LC	1	0.54	0	0.00
Plain Sunbird (*Anthreptes simplex*)	LC	0	0.00	1	0.67
Red-throated Sunbird (*Anthreptes rhodolaea*)	LC	0	0.00	1	0.67
Timaliidae					
Black-throated Babbler (*Stachyris nigricollis*)	NT	1	0.54	23	15.33
Short-tailed Babbler (*Trichastoma malaccanse*)	LC	0	0.00	9	6.00
Black-capped Babbler (*Pellorneum pyrrogenys*)	LC	2	1.09	5	3.33
Fluffy-back Tit Babbler (*Macronous ptilosus*)	NT	0	0.00	14	9.33
Chestnut-winged Babbler (*Stachyris erythroptera*)	LC	0	0.00	17	11.33
Bold- striped Tit Babbler (*Macronous bornensis*)	LC	17	9.24	3	2.00
Chestnut-rumped Babbler (*Stachyris maculata*)	NT	4	2.17	1	0.67

White-chested Babbler (*Trichastoma rostratum*)	NT	0	0.00	3	2.00
Scaly-crowned Babbler (*Malacopteron cinereum*)	LC	0	0.00	1	0.67
Pycnonotidae					
Yellow-vented Bulbul (*Pycnonotus goiavier*)	LC	56	30.43	0	0.00
Hook-billed Bulbul (*Setornis criniger*)	V	0	0.00	7	4.67
Olive winged Bubul (*Pycnonotus plumosus*)	LC	3	1.63	2	1.33
Black and white Bulbul (*Pycnonotus melanoleucos*)	NT	1	0.54	0	0.00
Hairy-backed Bulbul (*Trichastoma criniger*)	LC	1	0.54	0	0.00
Alcedinidae					
Stork-billed Kingfisher (*Pelargopsis capensis*)*	LC	1	0.54	2	1.33
Rufous Backed Kingfisher (*Ceyx rufidorsa*)*	LC	1	0.54	7	4.67
Blue-eared Kingfisher (*Alcedo meninting*)*	LC	0	0.00	6	4.00
Strigidae					
Brown Hawk Owl (*Ninox scutulata*)*	LC	0	0.00	1	0.67
Picidae					
Maroon Woodpecker (*Blythipicus rubiginosus*)*	LC	0	0.00	1	0.67
Buff-necked Woodpecker (*Meiglyptes tukki*)*	NT	0	0.00	3	2.00
Rufous Piculet (*Sasia abnormis*)*	LC	7	3.80	5	3.33
Cisticolidae					
Ashy Tailorbird (*Orthotomus ruficeps*)	LC	4	2.17	0	0.00
Rufous-tailed Tailorbird (*Orthotomus sericeus*)	LC	18	9.78	1	0.67

Yellow-bellied Prinia (*Prinia flaviventris*)	LC	16	8.70	0	0.00
Cuculidae					
Plaintive Cuckoo (*Cacomantis merulinus*)	LC	8	4.35	0	0.00
Banded bay Cuckoo (*Cacomantis sonneratii*)	LC	1	0.54	0	0.00
Monarchidae					
Black-naped Monarch (*Hypothemis azurea*)	LC	0	0.00	5	3.33
Estrildidae					
Dusky Munia (*Lonchura fuscans*)	LC	1	0.54	8	5.33
Muscicapidae					
Oriental Magpie Robin (*Copsychus saularis*)	LC	12	6.52	0	0.00
Grey-chested Jungle-flycatcher (*Rhinomyias umbratilia*)	LC	0	0.00	4	2.67
Caprimulgidae					
Large-tailed Nightjar (*Caprimulgus macrurus*)	LC	3	1.63	0	0.00
Bonaparte's nightjar (*Caprimulgus concretus*)	V	0	0.00	1	0.67
Cettiidae					
Yellow-bellied Warbler (*Abroscopus superciliaris*)	LC	2	1.09	0	0.00
Rhipiduridae					
Pied Fantail (*Rhipidura javanica*)	LC	9	4.89	1	0.67
Rallidae					
White-breasted Waterhen (*Amaurornis phoenicurus*)	LC	3	1.63	0	0.00
Accipitridae					

Chinese Sparrowhawk (*Accipiter soloensis*)	LC	1	0.54	0	0.00
Dicaeidae					
Orange-bellied Flowerpecker (*Dicaeum trigonostigma*)	LC	1	0.54	2	1.33
Yellow-breasted Flowerpecker (*Prionochilus maculatus*)	LC	0	0.00	3	2.00
Columbidae					
Spotted Dove (*Streptopelia chinensis*)	LC	1	0.54	0	0.00
Sturnidae					
Asian Glossy Starling (*Aplonis panayensis*)	LC	1	0.54	0	0.00
Trogonidae					
Diard's Trogon (*Harpactes diardii*)	NT	0	0.00	3	2.00
Aegithinidae					
Common Iora (*Aegithina tiphia*)	LC	2	1.09	0	0.00

Total individuals	184	150
Total species	30	31
Total effort (Net/hours)	5385	5400
Shanon Index	3.745	4.360
Margalef Index, R_1	5.561	5.987
Pielou Index, E	0.763	0.880
Testing of Significance Difference	P<0.05	

Remarks: * Protected animals under Sarawak Wild Life Protection Ordinance, 1998

The IUCN Red List of Threatened Species: (NT : Near Threatened; V : Vulnerable and LC : Least Concern)

Table 3. Bird species that are recorded only in DFM, only in CMC and in both DFM and CMC

Only in DFM	Only in CMC	Common to DFM and CMC
Asian Glossy Starling	Black-naped Monarch	Black-capped Babbler
Ashy Tailorbird	Blue-eared Kingfisher	Black-throated Babbler
Banded bay Cuckoo	Bonaparte's nightjar	Bold- striped Tit Babbler
Black and white Bulbul	Brown Boobook	Chestnut-rumped Babbler
Brown-throated Sunbird	Buff-necked Woodpecker	Dusky Munia
Chinese Sparrowhawk	Chestnut-winged Babbler	Olive winged Bubul
Common Iora	Diard's Trogon	Orange-bellied Flowerpecker
Crimson Sunbird	Fluffy-back Tit Babbler	Pied Fantail
Hairy-backed Bulbul	Grey-chested Jungle-flycatcher	Ruby-cheeked Sunbird
Large-tailed Nightjar	Hook-billed Bulbul	Rufous Backed Kingfisher
Oriental Magpie Robin	Maroon Woodpecker	Rufous Piculet
Plaintive Cuckoo	Plain Sunbird	Rufous-tailed Tailorbird
Spotted Dove	Purple-naped Sunbird	Stork-billed Kingfisher
White-breasted Waterhen	Red-throated Sunbird	
Yellow-bellied Prinia	Scaly-crowned Babbler	
Yellow-bellied Warbler	Short-tailed Babbler	
Yellow-vented Bulbul	White-chested Babbler	
	Yellow-breasted Flowerpecker	

Table 3 showed that the species composition in CMC and DFM is quite different. CMC recorded 18 species of bird from family Nectariidae, Timaliidae, Pycnonotidae, Alcedinidae, Strigidae, Picidae, Monarchidae, Muscicapidae, Dicaeidae and Trogonidae which was not present in oil palm plantation. These species might be restricted to forest only and does not prefer oil palm plantation as their habitat. Seventeen species from family Nectariidae, Pycnonotidae, Cisticolidae, Cuculidae, Muscicapidae, Caprimulgidae, Cettiidae, Rallidae, Columbidae, Sturnidae and Aegithinidae of bird were recorded only in oil palm plantation suggesting that these birds might be prefer the plantation as their

habitat. Meanwhile a total of 13 species of birds were recorded in both sites indicating that these species are adaptable and can use both habitats.

The two dominant groups of bird in the study area are babblers and bulbuls, with Yellow-vented bulbul being the dominant species in oil palm plantation. Table 4 show how different species of bulbuls use the different habitats in the study area. Hook-billed bulbul seems to prefer peat swamp forest while Yellow-vented bulbul, Hairy-backed Bulbul and Black and White Bulbul seems to prefer oil palm plantation. Olive-winged Bulbul seems to be in between these two extreme species in terms of their distribution.

Table 4. Distribution of bulbuls at DFM, Boundary and CMC.

Bulbul species	CMC	Boundary	DFM
Hook-billed Bulbul	7	1	0
Olive-winged Bulbul	2	5	3
Black and White Bulbul	0	0	1
Hairy-backed Bulbul	0	1	1
Yellow-vented Bulbul	0	8	56

4.2 Comparing bird species richness and abundance at DFM and CMC at difference distances from boundary

Table 5 shows the total number of species and individual of bird recorded at difference distances from boundary. The result showed that oil palm site located 200 m away from boundary recorded the highest total number of species and individuals (25 species and 102 individuals) of birds followed by CMC at distance 500 m away from the boundary site and oil palm site that located 500 m from the boundary site. However, the CMC site that is located 200 m from boundary recorded the lowest total number of species as compared to other sites.

Table 5. Total number of species and individuals of birds recorded at different distance from the boundary site to DFM or CMC

Family	Common Name	Species Name	DFM	CMC	DFM	CMC
			200 m		500 m	
Nectarinidae	Purple-naped Sunbird	*Hypogramma hypogrammicum*		2		2
	Ruby-cheeked Sunbird	*Anthreptes singalensis*	2	1	2	5
	Brown-throated Sunbird	*Anthreptes malacensis*	1		1	
	Crimson Sunbird	*Aethopyga siparaja*	1			
	Plain Sunbird	*Anthreptes simplex*				1
	Red-throated Sunbird	*Anthreptes rhodolaema*				1
Timaliidae	Black-throated Babbler	*Stachyris nigricollis*	1	6		17
	Short-tailed Babbler	*Trichastoma malaccanse*		6		3
	Black-capped Babbler	*Pellorneum pyrrogenys*	1	1	1	4
	Fluffy-back tit Babbler	*Macronous ptilosus*		8		6
	Chestnut-winged Babbler	*Stachyris erythroptera*		10		7
	Bold- striped Tit Babbler	*Macronous bornensis*	9	3	8	
	Chestnut-rumped Babbler	*Stachyris maculate*	4	1		
	White-chested Babbler	*Trichastoma rostratum*				3
	Scaly-crowned Babbler	*Malacopteron cinereum*				1
Pycnonotidae	Yellow-vented Bulbul	*Pycnonotus goiavier*	31		25	

	Hook-billed Bulbul	*Setornis criniger*		3		4
	Olive winged Bubul	*Pycnonotus plumosus*	2	2	1	
	Black and white Bulbul	*Pycnonotus melanoleucos*	1			
	Hairy-backed Bulbul	*Trichastoma criniger*			1	
Alcedinidae	Stork-billed Kingfisher	*Pelargopsis capensis*	1	1		1
	Rufous Backed Kingfisher	*Ceyx rufidorsa*	1	3		4
	Blue-eared Kingfisher	*Alcedo meninting*				6
Strigidae	Brown Boobook	*Ninox scutulata borneensis*		1		
Picidae	Maroon Woodpecker	*Blythipicus rubiginosus*		1		
	Buff-necked Woodpecker	*Meiglyptes tukki*				3
	Rufous Piculet	*Sasia abnormis*	5	5	2	
Cisticolidae	Ashy Tailorbird	*Orthotomus ruficeps*	3		1	
	Rufous-tailed Tailorbird	*Orthotomus sericeus*	11	1	7	
	Yellow-bellied Prinia	*Prinia flaviventris*	9		7	
Cuculidae	Plaintive Cuckoo	*Cacomantis merulinus*	6		2	
	Banded bay Cuckoo	*Cacomantis sonneratii*	1			
Monarchidae	Black-naped Monarch	*Hypothemis azurea*		2		3
Estrildidae	Dusky Munia	*Lonchura fuscans*		8	1	
Muscicapidae	Oriental Magpie Robin	*Copsychus saularis*	3		9	
	Grey-chested Jungle-flycatcher	*Rhinomyias umbratilia*				4

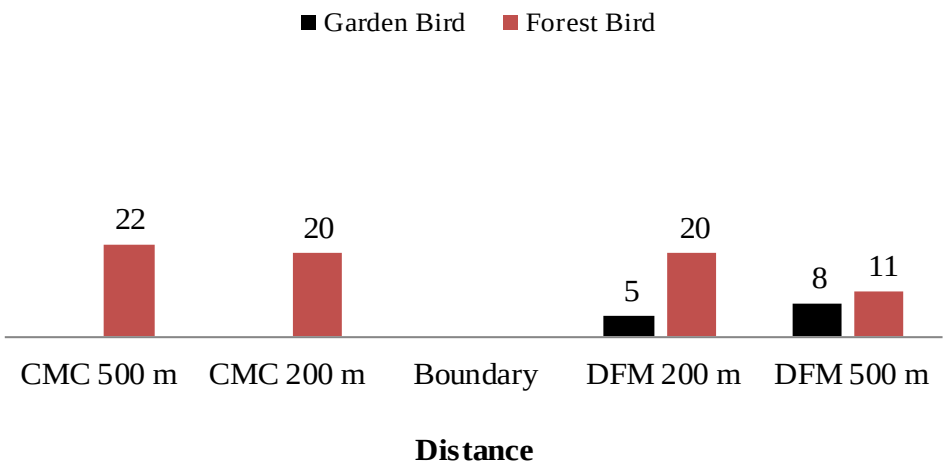
Caprimulgidae	Large-tailed Nightjar	*Caprimulgus macrurus*	3			
	Bonaparte's nightjar	*Caprimulgus concretus*				1
Cettiidae	Yellow-bellied Warbler	*Abroscopus superciliaris*	2			
Rhipiduridae	Pied Fantail	*Rhipidura javanica*	4	1	5	
Rallidae	White-breasted Waterhen	*Amaurornis phoenicurus*	1		2	
Accipitridae	Chinese Sparrowhawk	*Accipiter soloensis*	1			
Dicaeidae	Orange-bellied Flowerpecker	*Dicaeum trigonostigma*	1			2
	Yellow-breasted Flowerpecker	*Prionochilus maculatus*				3
Columbidae	Spotted Dove	*Streptopelia chinensis*			1	
Sturnidae	Asian Glossy Starling	*Aplonis panayensis*			1	
Trogonidae	Diard's Trogon	*Harpactes diardii*				3
Aegithinidae	Common Iora	*Aegithina tiphia*			2	
Total Species			25	19	20	22
Total Individual			102	79	66	84

Eight species of bird (Table 6) recorded in this study were categorised as garden bird based on list established by Malaysian Nature Society (2013). According to Malaysian Nature Society (2013), garden birds are frequently spotted in the garden of a typical Malaysian residential area. Garden birds are important because it contributes towards better understanding of the surrounding environment and how they react to environmental factors. The rest of the birds (40 species) recorded in this study are therefore categorised as forest birds.

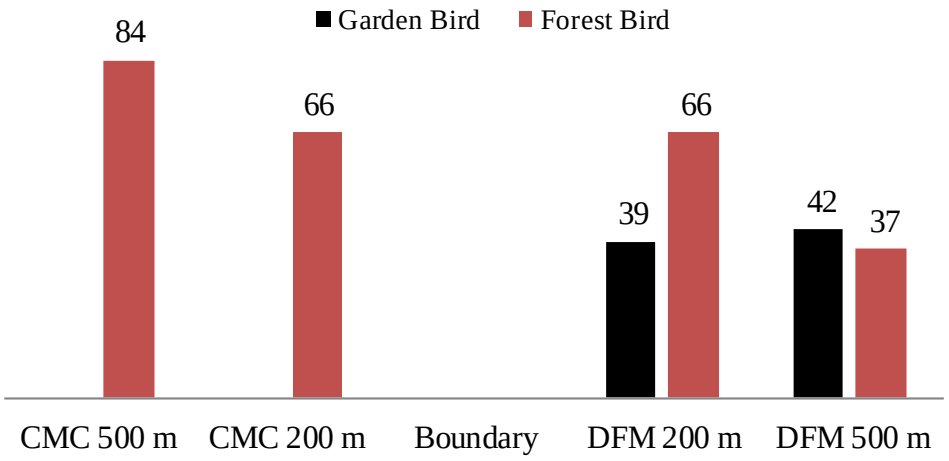
Table 6. List of garden birds recorded in this study (based on Malaysian Nature Society, 2013)

Garden Bird
Asian Glossy Starling
Ashy Tailorbird
Brown-throated Sunbird
Common Iora
Oriental Magpie Robin
Spotted Dove
White-breasted Waterhen
Yellow-vented Bulbul

These birds were further divided into different distances where they have been captured. Figure 8 showed that the total number of species and individuals of forest and garden birds recorded at oil palm plantation and adjacent forest located at different distances (200 and 500 m) from boundary. This figure showed that many species of forest bird use oil palm plantation located next to forest edge compared to plantation interior.



(a)



(b)

Figure 8. Total number of species (a) and individuals (b) of garden and forest bird recorded at different distances (200m and 500m) from the boundary between oil palm plantation (DFM) and adjacent peat swamp forest (CMC)

The results showed a clear trend that the total number of species of forest bird decreased in number as we move from inside the peat swamp forest into oil palm plantation. The total number of species of garden birds also decreased as we moved from oil palm plantation into forest. Not a single species of garden birds was recorded in adjacent peat swamp

forest. This result suggest that forest bird might be use oil palm plantation up to more than 500 m from the boundary area while garden birds does not use the peat swamp forest located more than 200 m from boundary area.

Table 7. List of forest birds and garden birds* present only at different distance from boundary area

Distance from boundary area	**CMC**	**DFM**
200 m	Brown Boobook Maroon Woodpecker	Banded bay Cuckoo Black and white Bulbul Chinese Sparrowhawk Crimson Sunbird Large-tailed Nightjar Yellow-bellied Warbler
500 m	Black-naped Monarch Blue-eared Kingfisher Bonaparte's nightjar Buff-necked Woodpecker Diard's Trogon Grey-chested Jungle-flycatcher Red-throated Sunbird Scaly-crowned Babbler Yellow-breasted Flowerpecker White-chested Babbler	Asian Glossy Starling* Common Iora* Spotted Dove* Hairy-backed Bulbul

Table 7 showed the list of forest and garden birds that are present at different distance from boundary area. The results showed high number of forest bird species are restricted to forest located 500 m from boundary area while less number of forest bird and high number of garden bird species are present only in oil palm plantation located 500 m from the boundary area.

Table 8. List of species of bird common to two different site that were located at different distance from boundary area

Distance from boundary area (number of shared species in bracket)	**Shared species**
CMC 200 m and DFM 200 m (11 species)	Black-capped Babbler Black-throated Babbler Bold-striped Tit Babbler Chestnut-rumped Babbler Olive winged Bubul Pied Fantail Ruby-cheeked Sunbird Rufous Backed Kingfisher Rufous Piculet Rufous-tailed Tailorbird Stork-billed Kingfisher
CMC 200 m and DFM 500 m (8 species)	Black-capped Babbler Bold-striped Tit Babbler Dusky Munia Olive winged Bubul Pied Fantail Ruby-cheeked Sunbird Rufous Piculet Rufous-tailed Tailorbird
DFM 200 m and CMC 500 m (6 species)	Black-capped Babbler Black-throated Babbler Orange-bellied Flowerpecker Ruby-cheeked Sunbird Rufous Backed Kingfisher Stork-billed Kingfisher
CMC 500 m and DFM 500 m (2 species)	Black-capped Babbler Ruby-cheeked Sunbird

Table 8 showed the list of bird that are common to two different sites that were located at different distance from boundary area. The result showed that the site closer to each other have higher shared species (CMC 200 m and DFM 200 m: 11 species; DFM 200 m and DFM 500 m: 12 species and CMC 200 m and CMC 500 m: 11 species) while the sites

further away from each other have lowest number of shared species (CMC 500 m and DFM 500 m: 2 species).

Figure 9 shows that the lowest Shannon index of species diversity (*H'*) was recorded at 500 m inside oil palm plantation while the highest index was recorded at 500 m inside the adjacent peat swamp forest. The assemblage of bird at CMC site located 500 m from the boundary has the most even relative abundance as compared to other sites, and this resulted in greater diversity index compared to other sites (Appendices 5, 6, 7 and 8).

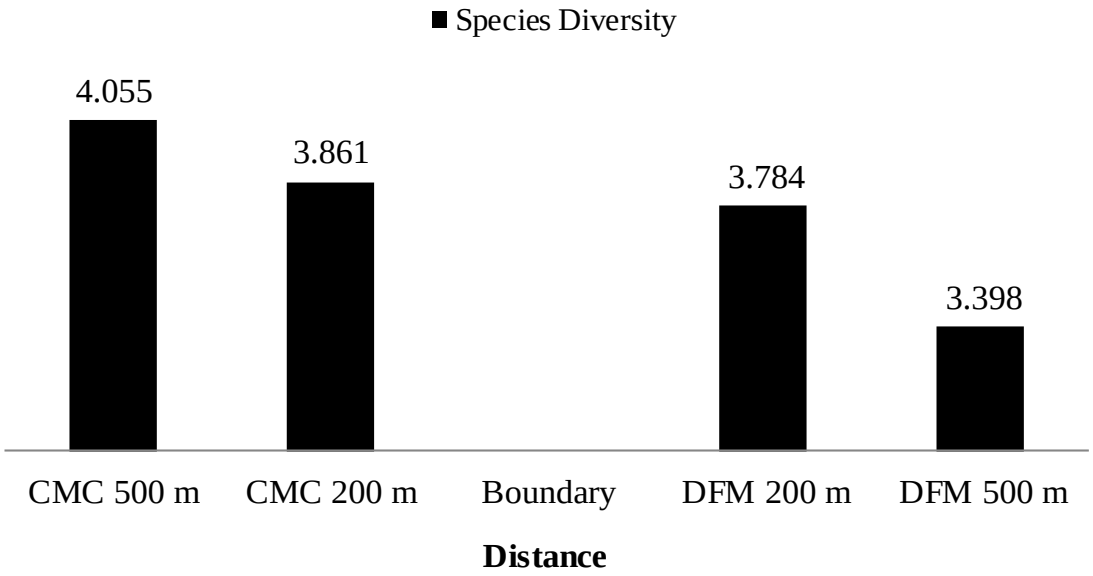


Figure 9. Shannon index (*H'*) of species diversity at different distances from boundary site

Calculation for significant difference (Appendix 9 to 14) between DFM 200 m and DFM 500 m, DFM 200 m and CMC 500 m, DFM 500 m and CMC 200 m, DFM 500 m and CMC 500 m, and CMC 200 m and CMC 500 m with Zar's modified t-test (Zar's 1996) showed that there were significant difference in term of bird diversity (Table 9). These results again indicate that sites furthest from each other have the least shared species. On the other hand, there was no significant difference between DFM 200 m and CMC 200 m.

Table 9. Zar's modified t-test calculation on Shannon Index at different distances from boundary

Test Criteria	Calculated p Value	Significant Value
DFM 200 m VS CMC 500 m	0.001	P<0.05
DFM 500 m VS CMC 200 m	0.001	P<0.05
DFM 500 m VSCMC 500 m	0.001	P<0.05
DFM 200 m VS CMC 200 m	0.275	P>0.05
DFM 200 m VS DFM 500 m	0.001	P<0.05
CMC 200 m VS CMC 500 m	0.002	P<0.05

4.3 Feeding guilds of birds in oil palm plantation and adjacent peat swamp forest

The mist-netted birds were classified into five categories (Table 10) of feeding guild using published information about feeding guild from Azhar *et al.* (2013) and Phillipps and Phillipps (2013).

Table 10. List of 48 bird species and five bird guilds recorded in Dufarm Oil Palm Plantation and Cermat Ceria Forest, Betong, Sarawak

Family Local Name (*Species name*)	Feeding Guild
Nectarinidae	
Purple-naped Sunbird (*Hypogramma hypogrammicum*)	Omnivore
Ruby-cheeked Sunbird (*Anthreptes singalensis*)	Omnivore
Brown-throated Sunbird (*Anthreptes malacensis*)	Omnivore
Crimson Sunbird (*Aethopyga siparaja*)	Omnivore
Plain Sunbird (*Anthreptes simplex*)	Omnivore
Red-throated Sunbird (*Anthreptes rhodolaea*)	Omnivore
Timaliidae	
Black-throated Babbler (*Stachyris nigricollis*)	Insectivore
Short-tailed Babbler (*Trichastoma malaccanse*)	Insectivore
Black-capped Babbler (*Pellorneum pyrrogenys*)	Insectivore

Fluffy-back tit Babbler (*Macronous ptilosus*)	Insectivore
Chestnut-winged Babbler (*Stachyris erythroptera*)	Insectivore
Bold- striped Tit Babbler (*Macronous bornensis*)	Insectivore
Chestnut-rumped Babbler (*Stachyris maculata*)	Insectivore
White-chested Babbler (*Trichastoma rostratum*)	Insectivore
Scaly-crowned Babbler (*Malacopteron cinereum*)	Insectivore
Pycnonotidae	
Yellow-vented Bulbul (*Pycnonotus goiavier*)	Omnivore
Hook-billed Bulbul (*Setornis criniger*)	Omnivore
Olive winged Bubul (*Pycnonotus plumosus*)	Omnivore
Black and white Bulbul (*Pycnonotus melanoleucos*)	Omnivore
Hairy-backed Bulbul (*Trichastoma criniger*)	Omnivore
Alcedinidae	
Stork-billed Kingfisher (*Pelargopsis capensis)*	Carnivore
Rufous Backed Kingfisher (*Ceyx rufidorsa*)	Carnivore
Blue-eared Kingfisher (*Alcedo meninting*)	Carnivore
Strigidae	
Brown Hawk Owl (*Ninox scutulata*)	Insectivore
Picidae	
Maroon Woodpecker (*Blythipicus rubiginosus*)	Insectivore
Buff-necked Woodpecker (*Meiglyptes tukki*)	Insectivore
Rufous Piculet (*Sasia abnormis*)	Insectivore
Cisticolidae	
Ashy Tailorbird (*Orthotomus ruficeps*)	Insectivore
Rufous-tailed Tailorbird (*Orthotomus sericeus*)	Insectivore
Yellow-bellied Prinia (*Prinia flaviventris*)	Insectivore
Cuculidae	
Plaintive Cuckoo (*Cacomantis merulinus*)	Insectivore
Banded bay Cuckoo (*Cacomantis sonneratii*)	Insectivore
Monarchidae	
Black-naped Monarch (*Hypothemis azurea*)	Insectivore
Estrildidae	
Dusky Munia (*Lonchura fuscans*)	Granivore

Muscicapidae	
Oriental Magpie Robin (*Copsychus saularis*)	Insectivore
Grey-chested Jungle-flycatcher (*Rhinomyias umbratilia*)	Insectivore
Caprimulgidae	
Large-tailed Nightjar (*Caprimulgus macrurus*)	Insectivore
Bonaparte's nightjar (*Caprimulgus concretus*)	Insectivore
Cettiidae	
Yellow-bellied Warbler (*Abroscopus superciliaris*)	Insectivore
Rhipiduridae	
Pied Fantail (*Rhipidura javanica*)	Insectivore
Rallidae	
White-breasted Waterhen (*Amaurornis phoenicurus*)	Omnivore
Accipitridae	
Chinese Sparrowhawk (*Accipiter soloensis*)	Carnivore
Dicaeidae	
Orange-bellied Flowerpecker (*Dicaeum trigonostigma*)	Omnivore
Yellow-breasted Flowerpecker (*Prionochilus maculatus*)	Omnivore
Columbidae	
Spotted Dove (*Streptopelia chinensis*)	Frugivore
Sturnidae	
Asian Glossy Starling (*Aplonis panayensis*)	Omnivore
Trogonidae	
Diard's Trogon (*Harpactes diardii*)	Insectivore
Aegithinidae	
Common Iora (*Aegithina tiphia*)	Insectivore

More than 50% of the birds recorded in this study are insectivores followed by omnivores (29.64%), carnivores (5.38%), granivores (2.70%) and frugivores (0.30%). DFM with five feeding guild supported slight higher feeding guild of understory birds in this study than CMC with four feeding guild (Figure 10). No frugivore bird species were recorded in CMC, but insectivore, granivore and carnivore bird species were abundant as compared to

DFM. Few granivore and carnivore birds were recorded in oil palm landscapes but generalists or omnivores species were abundant in DFM.

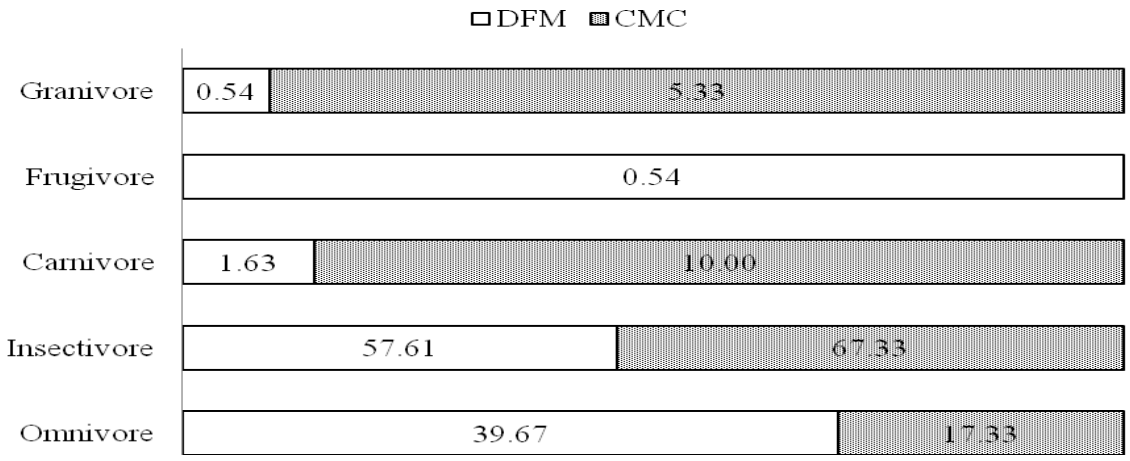
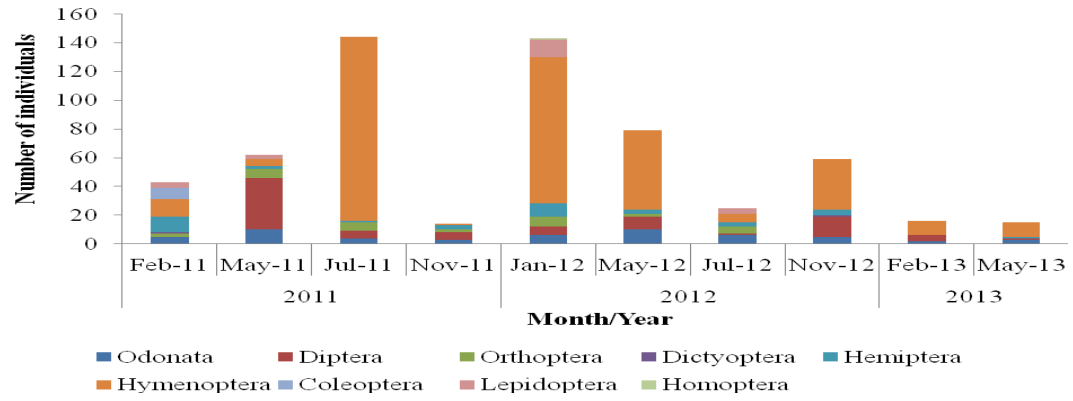


Figure 10. Percentage of feeding guilds of understory birds in DFM and CMC

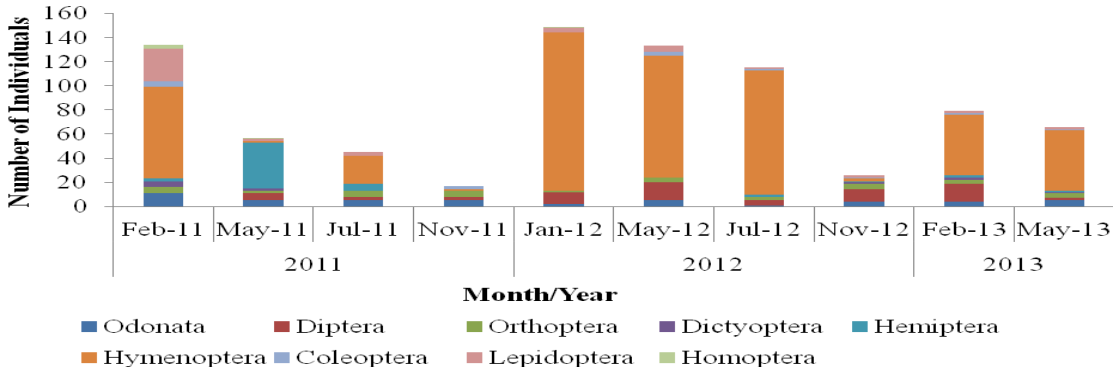
Few insectivore species were recorded in oil palm plantation than adjacent peat swamp forest. However, omnivore species was more diverse in DFM as compared with CMC. Carnivore and granivore species was equally present in both sites with three and one species each, however there was high abundance of both feeding guild in CMC.

4.4 Distribution of food resources in oil palm plantation and adjacent peat swamp forest

By walking through mist-nets trail, food resources such as fruit and insect that are available along the trail were identified during sampling period. The temporal distribution of insect in oil palm plantation was variable among months of sampling.



(a) DFM



(b) CMC

Figure 11. Distribution of insect orders in DFM and CMC at different sampling months and years

Figure 11, showed that July 2011 and January 2012 recorded high abundance of insect as compared with other months in DFM while in CMC insect was recorded abundance in Feburary 2011, January 2012 and May 2012. Order Hymenoptera was the most abundant insect recorded in oil palm plantation and adjacent forest for most of the months. The month of November 2011 and July 2012 recorded the lowest abundance of insect in oil palm plantation especially in November 2011 when no members of the order Hymenoptera were recorded. In CMC, November 2011 and 2012 recorded the lowest abundance of insect as compared with other months.

The overall results of insect survey (Figure 12) on the line transect where mist-nets were set up in DFM showed that a total of 687 individuals from nine orders were recorded and in CMC a total of 821 individuals from nine orders were present. The order Hymenoptera especially from family Formicidae was the most abundant Order in this area followed by order Diptera, Odonata and Hemiptera. Homoptera was the least abundant insect order in DFM plantation. In CMC, order Hymenoptera was also the most abundant followed by order Diptera, Hemiptera, Lepidoptera and Odonata. The least abundant insect order in CMC was Homoptera similar to DFM.

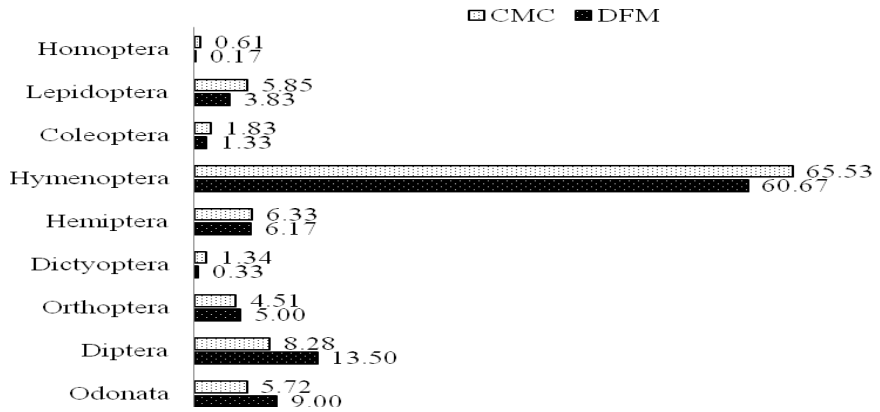


Figure 12. Percentage of individuals of each order of insect recorded in DFM and CMC for ten times sampling through line transect survey

In terms of fruit survey along the line transect were carried in oil palm plantation and adjacent peat swamp forest. In oil palm plantation, *Melastoma* sp. was the only species of plant that was recorded to produce fruit besides oil palm fruit. In CMC, *Endiandra coriacea, Medinilia* sp., *Baccaurea bracteata, Elaocarpus* sp., *Ilex cymosa, Lithocarpus* sp. and *Embelia ribes* were recorded to bear fruit from March to July.

4.5 Frequency of birds flying between oil palm plantation and forest at boundary zone

A total of 92 birds comprised of 28 species from 18 families were identified and recorded through mist-netting method at the boundary between DFM and CMC (Appendix 15). The most diverse family caught in this site was Pycnontidae with four species, followed by Nectariniidae, Timalidae and Cisticolidae with three species each. There were six families of bird captured in the boundary site with only one individual for each species; Ramphastidae, Sylviidae, Pittidae, Tytonidae and Strigidae. The most abundant species is Bold- striped Tit Babbler (*Macronous bornensis*), representing 16.3% of the total of birds caught in this site, followed in order by Pacific Swallow (14.13%) and Yellow-vented Bulbul (7.61%). Blue-winged Pitta (*Pitta moluccensis*) recorded in this site is listed as totally protected animal and three other species of bird (Stork-billed Kingfisher, Rufous Piculet and Orential Bay Owl are listed as protected animal by SWLPO, 1998. This site also harbours three Near Threatened species (Chestnut-rumped Babbler, Reddish Scops Owl and Red-crowned Barbet) and one Vulnerable species (Hook-billed Bulbul). A total of five species of garden birds (Brown-throated Sunbird, Pacific Swallow, Oriental Magpie Robin, Yellow-vented Bulbul and Ashy Tailorbird) were recorded at the boundary site.

4.5.1 Direction

The number of birds hitting the net from the oil palm side is always higher than from the forest side. The data showed that the preferred destination for the birds is forest, indeed a total of 60 (23 species) birds were recorded flying from oil palm towards the forest compared to 32 (15 species) flying from forest towards the plantation (Table 11). Overall the calculated chi-squared value (Appendix 16), $\chi 2$ is 8.52 which shows significantly

($p<0.01$) more birds hitting the boundary net from the oil palm side, suggesting that the peat swamp forest is a preferred destination for the bird.

Table 11. List of birds hitting the boundary nets either from oil palm to forest or forest to oil palm

Oil palm to forest	**Forest to oil palm**
Chestnut-rumped Babbler	Chestnut-rumped Babbler
Bold- striped Tit Babbler	Bold- striped Tit Babbler
Scaly-crowned babbler	Yellow-vented bulbul
Little spiderhunter	Olive winged bubul
Yellow-vented bulbul	Rufous-tailed tailorbird
Olive winged bubul	Yellow-bellied prinia
Rufous-tailed tailorbird	Reddish Scope owl
Yellow-bellied prinia	Dusky munia
Plaintive cuckoo	Plaintive cuckoo
Large-tailed Nightjar	Sliver rumped Spinetail
Orential Bay Owl	Pacific Swallow
Pacific Swallow	Oriental magpie robin
Oriental magpie robin	Pied fantail
Grey-chested Jungle-flycatcher	Stork-billed kingfisher
Stork-billed kingfisher	Rufous Piculet
Oriental reed warbler	
Ruby-cheeked sunbird	
Hairy-backed bulbul	
Dusky munia	
Sliver rumped Spinetail	
Rufous Piculet	
Blue-winged Pitta	
Red-crowned Barbet	

In this study only Pacific Swallow (A08454) and Bold-striped Tit-babbler (A08440) were recaptured at the boundary net. Pacific Swallow was first captured during the 6th sampling occasion where this bird hit the boundary net from oil palm to forest in the morning (0950 am) and recaptured at the same sampling site in late evening (1745 pm) also from oil palm plantation to forest. This seems to indicate that this bird had somehow crossed the

boundary back into the oil palm plantation without hitting the boundary net. For Bold-striped Tit-babbler, was firstly captured during 6th sampling in the morning (0845 am) hitting the boundary net from oil palm to forest. When recaptured again on the 7th sampling in the morning (0900 am) it was hitting the boundary net from forest to oil palm.

4.5.2 Time of day

Table 12 shows summarised the data on frequency of birds hitting the boundary nets at different times of the day. Most of the bird are active in the morning (54 hits) compared to afternoon (23 hits) and midday (15 hits). This result showed that most of the birds are active in the morning as compared to midday and late afternoon. Chi square test (Appendix 16) give a value of 27.61 which is significantly different at $p<0.01$. Hence this test supports this study hypothesis that the activity of bird, as indicated by the number entering the net from plantation and from forest in the morning, midday and late afternoon is significantly different.

Table 12. Summary of total number of birds entering the boundary net according to different times, Betong, Sarawak

	Morning 6am-9.59am	Middle of the day 10 am – 3.59 pm	Late afternoon (4pm-6pm)	**Total**
Total of Individual	54	15	23	**92**
Total species	20	11	15	**28**

4.6 Distribution and the diet of *P. goiavier* in oil palm plantation on peat

A total of 56 individuals of *P. goiavier* had been recorded in DFM through mist-netting methods and no single species of the bird was recorded in CMC. The distribution of this bird in DFM throughout the study period (Figure 13) showed high abundance of *P.*

goiavier in February while November recorded the lowest number of this species. In November 2012 not a single *P. goiavier* was recorded.

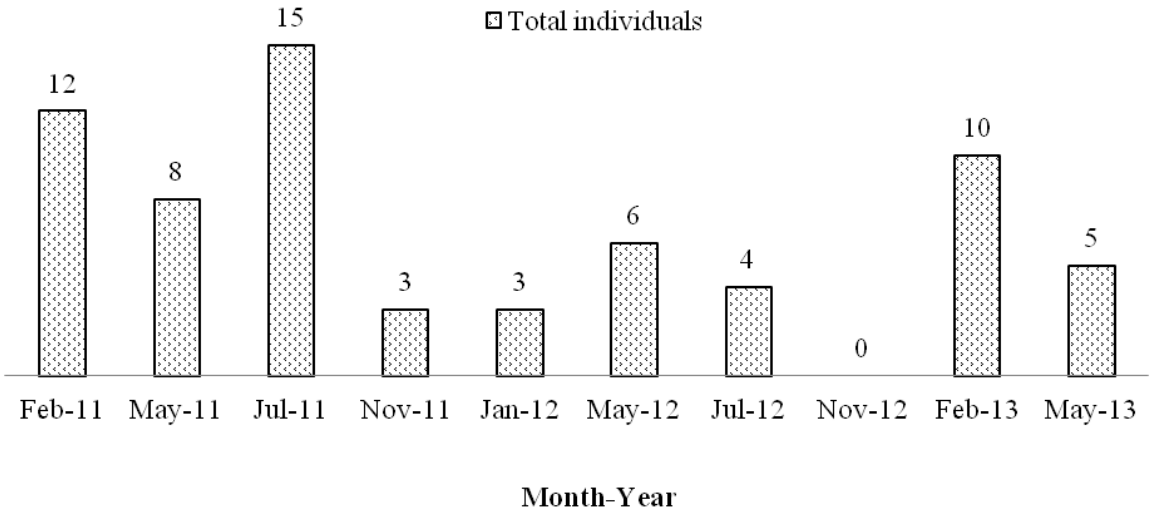


Figure 13. Distribution of *P. goiavier* in DFM at different months and years

Out of 56 individuals of *P. goiavier* recorded in DFM, 45 individuals were dissected to extract their stomach content. The content of the stomach were grouped according to the Orders and Familes (Appendix 17).

Table 13. Total number of species and individuals of plant, annelids and insects according to different order and family found in stomach of Yellow-vented Bulbul at DFM

	Order	Family	Number of species	Number of individual
Annelida	Haplotaxida		2	2
Insects	Diptera	Culicidae	3	3
	Hemiptera	Unidentified	1	1
	Hymenoptera	Formicidae	1	1
	Homoptera	Cicadellidae	1	2
	Coleoptera	Staphylinidae	1	1
		Scolytidae	1	1
		Curculionidae	1	30
	Unidentified		1	1

Table 13 shows the total number of species and individual plant, annelids and insects according to different order and family found in stomach of Yellow-vented Bulbul at DFM (Appendix 18 and 19). Worms and plant parts were also recorded if present. Some insect parts that had been digested could not be identified were recorded as unidentified parts. Examination of stomach content of *P. goiavier* showed that they feed on insects as well as on annelids, small berries, leaflet and oil palm fruitlet (Appendix 19).

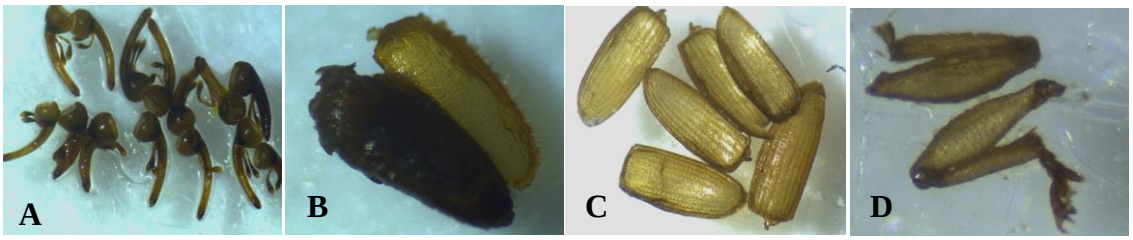


Figure 14. *Elaeidobius kamerunicus* parts found in *P. goiavier* (A) Rostrum and antenna, (B) Body, (C) Elytra and (D) Legs

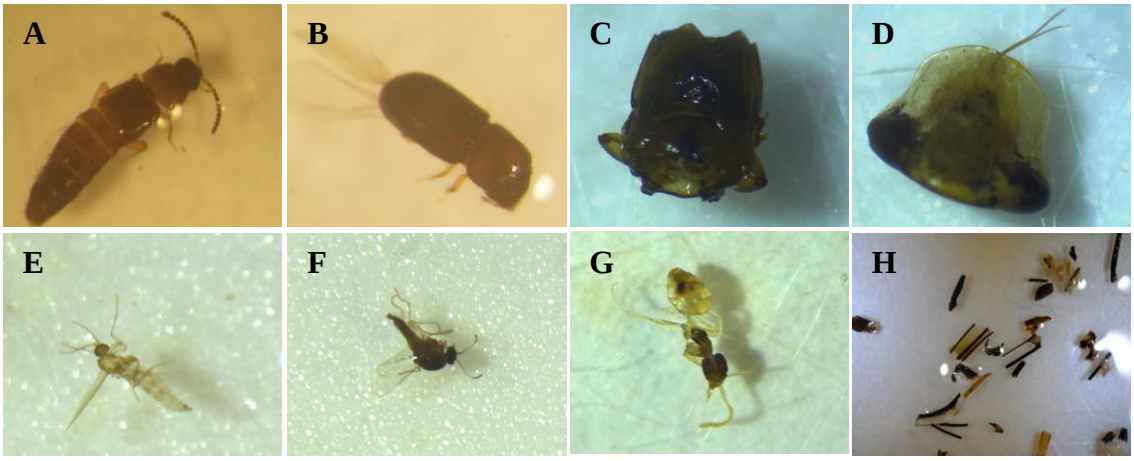


Figure 15. Some of the insects parts found in *P. goiavier* gut (A) Order Coleoptera; Family Staphylinidae (B) Order Coleoptera; Family Scolytidae (C) Order Homoptera; Family Cicadellidae (D) Order Homoptera; Mouth part (E) Order Diptera; Family Culicidae; (F) Order Diptera; Family Culicidae (G) Order Hymenoptera; Family Formicidae (H) Order Hemiptera; Hind wings

Figure 16. Other items found in *P. goiavier* gut (A) Class Annelida; earthworm (B) Order Annelida (C) Small berries (D) oil palm fibres (D) oil palm fibres and grass (F) Grass part

In terms of diet, this species feed mostly on the pollinator of oil palm from family Curculionidae, *Elaeidobius kamerunicus* (Figure 14) from Order Coleoptera 12 individuals of *P. goiavier* were found to have this insect in their gut. A total of 75% of the total insects (40 individuals) recorded in their gut was oil palm pollinating weevil. This insect was recorded higher for birds that captured in the month of May. Besides that, other Families

under Order Coleoptera found in this bird's gut were Staphylinidae and Scolytidae with 2.5% each from the total individuals of insect recorded in their gut. Family Culicidae (mosquitoes) was the second most abundant insect consumed by this species with 7.5%, respectively (Figure 15). This species also feed on ants (Order Hymenoptera), leafhopper (Order Homoptera), and bugs (Order Hemiptera). A total of eight species were recorded feeding on plant species. In term of fruit, two individuals of *P. goiavier* were eating oil palm fruitlets while other two individuals feed on unidentified species of small berries (Figure 16). This result showed that, *Melastoma* sp. is not the only fruiting plant in the estate because there were unidentified berries were recorded in their stomach.

The Ivelev's electivity index was used to measure the degree of selection by the predator towards a particular prey species. Table 14 showed the Ivlev's electivity index for different insect orders by Yellow-vented Bulbul.

Table 14. Ivlev's electivity index of different insect orders

No.	Order of Insect	Relative abundance of prey item in the gut, *ri*	Relative abundance of the same prey item in the environment, *pi*	Measure of electivity, E
1)	Coleoptera	85.37	1.33	0.97
2)	Homoptera	2.44	0.17	0.87
3)	Diptera	7.32	13.50	-0.30
4)	Hemiptera	2.44	6.17	-0.43
5)	Hymenoptera	2.44	60.70	-0.92
6)	Odonata	0.00	9.00	-1
7)	Orthoptera	0.00	5.00	-1
8)	Dictyoptera	0.00	0.33	-1
9)	Lepidoptera	0.00	3.83	-1

Result showed that, the Orders Coleoptera and Homoptera was actively selected (+0.97 and +0.89) as a prey items by *P. goiavier*. Hence, the abundance of the pollinating weevil (Order Coleoptera; Curculionidae and Order Homoptera: Cicadae) in oil palm plantation was reflected as the main food source for this adaptable species. Order like Hymenoptera (-0.97) indicate negative values is closer to -1 which meant some avoidance or inaccessibility of the prey item in the environment. While for Orders Hemiptera (-0.43) and Diptera (-0.30) are closer to 0 meaning *P. goiavier* opportunistically select prey based on abundance. *P. goiavier* completely avoid orders Odonata, Orthoptera, Dictyoptera and Lepidoptera in the environment where values for electivity index are -1 each. These higher negative values meant that prey items are present in the environment but was absent in their gut.

4.7 Recaptured Data

All birds captured at CMC and DFM were processed at boundary site and released there. Recaptured data showed that a total of 24 individuals of birds from 16 species were recaptured at least twice during the sampling period (Appendix 20). The most frequent individual was Rufous-backed Kingfisher (Ring No: A07648) which was recaptured five times at CMC site only. This bird was recaptured at CMC 200 m and also at CMC 500 giving a possible home range of 300 m for this bird. This species was also recorded in DFM.

A total of nine and eleven individuals were recaptured only at CMC and DFM respectively (Figure 17) while four individuals were recaptured at both sites (Grey-chested Jungle Flycatcher, Stork-billed Kingfisher, Purple-naped Sunbird and Rufous Piculet). The home range of Grey-chested Jungle Flycatcher, Stork-billed Kingfisher and Purple-naped

Sunbird is 1000 m where these individuals were first captured at DFM 500 m then recaptured at CMC 500 m. While for Rufous Piculet, it home range is 400 m where first captured was at DFM 200 m and then recaptured at CMC 200 m. Hence, this result strongly indicates that recaptured individuals have strong site fidelity and wide dispersal due perhaps to abundant food resources in recaptures site and closed population.

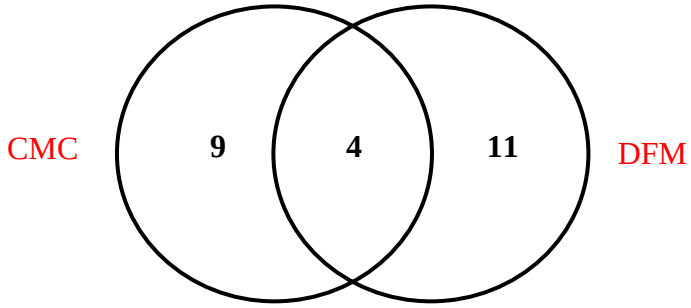


Figure 17. Total number of recaptured individuals at CMC and DFM

4.8 Cumulative graph

The cumulative number of species of bird captured in the CMC and DFM is shown in the Figure 18. The cumulative species graph for CMC shows it has reached an asymptote level during the sampling period. In contrast the cumulative graph for DFM is still rising and has not shown any sign of levelling off to reach asymptote suggesting more species could be recorded if sampling continues.

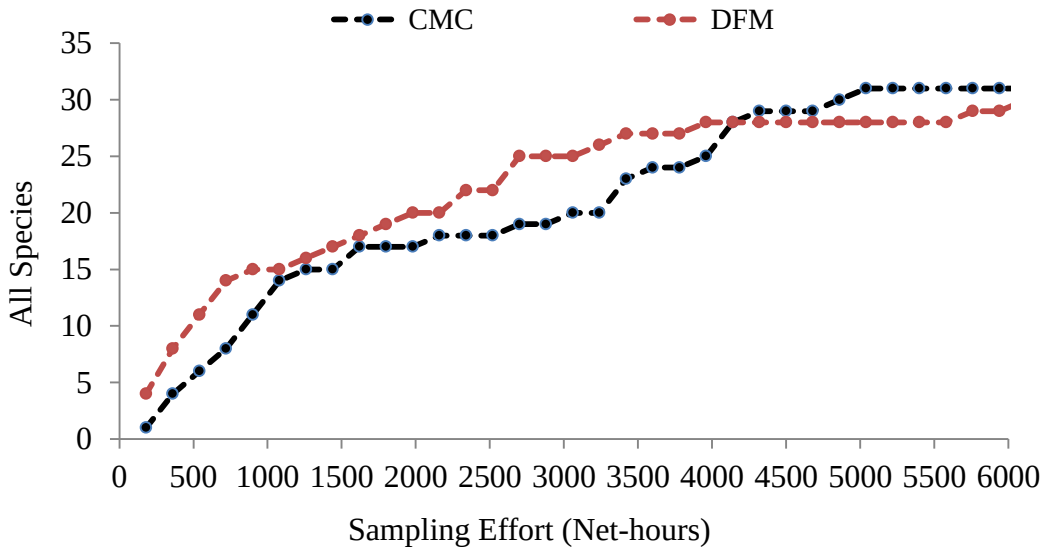


Figure 18. Species accumulative curve of birds at (a) DFM and (b) CMC for 34 days of sampling

CHAPTER 5

DISCUSSIONS

5.1 Bird species diversity, richness and abundance at DFM and CMC

Many studies (Fitzhebert *et al.*, 2008; Danielsen *et al.*, 2009; Yule, 2010) have reported a loss of biodiversity when forest is converted to plantation. Koh *et al.* (2011) predicted using species-area model that conversion of about 100, 000 ha of peat swamp forest into oil palm plantation in Sarawak will result in the loss of 2.9% of forest dwelling bird species. The same issue is an addressed in the current study how will bird assemblage be affected by conversion of logged peat swamp forest and oil palm plantation.

In the current study bird survey carried out in an oil palm plantation on peat (DFM) and in the adjacent peat swamp forest (CMC) using mist-netting method. This method is restricted to birds that used the understorey between 0.2 to 3 m above the ground level (Rahman and Tuen, 2006). The results show that the bird species richness in oil palm plantation (30 species) is similar to the adjacent peat swamp forest (31 species). This might be due to the proximity the sampling sites (oil palm plantation and adjacent peat swamp forest). Besides that, the presence of natural cover crop such as ferns and grasses in the oil palm plantation ehanced birds diversity (Jambri *et al.*, 2012).

In this study, the oil palm plantation (184 individuals) recorded high abundance of birds as compared with adjacent forest (150 individuals). The species abundance of birds was high in oil palm plantation due to to the present of dominant species, Yellow-vented Bulbul with 30.4% from the total individuals of bird in oil palm plantation, while in the adjacent peat swamp forest 15.33% from the total individuals of birds recorded in this site was

dominant species, the Black-throated Babbler. Hence, total number of dominant species in oil palm plantation (56 individuals of Yellow-vented Bulbul) is higher as compared with adjacent forest (23 individuals of Black-throated Babbler). The conversion of forest areas to agricultural areas may cause the number of forest bird species to decrease (Waltert *et al.*, 2004) and the number of adaptable species to increase (Aratrakon *et al*., 2006). This phenomenon happen due to oil palm plantation offering less niches, habitat structure less complex, and plant species were less diversified as compared to forest (Azman *et al.*, 2011; Fitzherbert, 2008; Koh and Wilcove, 2008; Fujioka and Yosida, 2001).

Diversity indices depend on number of species and relative abundance of birds recorded in each site. In this study, calculations of diversity indices indicate that adjacent peat swamp forest was more diversified site in term of understorey bird diversity than oil palm plantation. However the value of diversity indices does not indicate much about the community of birds that inhabit oil palm and peat swamp forest sites where the number of species are similar but the communities are different. The community can be different because of different species assemblages with different relative abundance. This differences might be related to the variety of food provided, offers of protection and shelter for birds to survive and reproduce (Rosli and Zakaria, 2011).

Hook-billed bulbul seems to prefer peat swamp forest while Yellow-vented bulbul seems to prefer oil palm plantation. According to Sheldon (1987) and Holmes and Wall (1989) Hook-billed bulbul is a threatened species that are rare in dipterocarp forests but common in Bornean peat swamp. The abundance of this species in peat swamp forest is probably due to ecological release from competitor which avoided that habitat (Sheldon *et al*., 2014). In this study none of this species of bird were recorded in oil palm plantation. The

number of this bird decrease as we move from forest to interior oil palm plantation.This result suggested that this species is unable to tolerate disturb area. It is different from Yellow-vented Bulbul which is one of the commonest of all bulbuls in Malaysia (Davison and Chew, 2008) and have wide ranging diet of both plants and animals (Tan, 2001). No Yellow-vented Bulbul was recorded in adjacent peat swamp forest. The number of this bird decrease as we move from plantation into deep forest and this finding supported by Wee (2009) who stated that this species can be found in almost all habitats, except in the deep forest.

Oil palm and forest support different communities because they offer different food resources. The family Timaliidae (babblers) that feed mostly on insect is the most diverse in adjacent peat swamp forest and while in oil palm plantation family Pycnonotidae (bulbuls) and family Timaliidae were the most diverse. Bulbul feed on insect and fruit in the oil palm plantation and this finding similar to Azhar *et al.* (2013). Four species of birds (White-breasted Waterhen, Rufous-backed Kingfisher, Stork-billed Kingfisher and Blue-eared Kingfisher) are linked to the presence of water in their habitat. At the study site water bodies such as small ponds and flooded-controlled ditches were common in the plantation and this offered foraging areas and opportunities for these species. Woodpeckers are bark-probing birds that feed on insect. Only a single species of the tiny woodpecker, Rufous Piculet, was recorded in DFM while three species (Buff-necked Woodpecker, Maroon Woodpecker and Rufous Piculet) were recorded in CMC. The abundance of woodpeckers in peat swamp forest is consistent with the finding of previous studies conducted by Peh *et al.* (2006), Sheldon *et al.* (2010) and Azhar *et al.* (2013).

In addition to food resources, predators are also one of the factors that influence the community of bird in a particular area. A single species of bird of prey was recorded in adjacent forest, for example Brown Hawk Owl, which feed on large insect and small vertebrates (Myers, 2009). In contrast the Chinese Sparrowhawk that has been reported to feed on frogs, lizards, small birds and small insects (Myers, 2009) was recorded only in DFM. Not only do these two predators partition themselves according to habitat type but they also partition themselves in terms of time of day they hunt, the owl hunt at night while the hawk hunt during the day time.

In this study, birds that are common to both habitats such as Black-capped Babbler, Black-throated Babbler, Bold-striped Tit-babbler, Chestnut-rumped Babbler, Dusky Munia, Olive-winged Bulbul, Orange-bellied Flowerpecker, Pied Fantail, Ruby-cheeked Sunbird, Rufous-tailed Kingfisher, Rufous Piculet, Rufous-tailed Tailorbird and Stork-billed Kingfisher can adapt themselves with two different microclimate (light intensity, temperature and humidity) and microhabitat (shrub cover, ground cover, litter depth, canopy cover and the number of trees) (Moradi *et al.*, 2009). In contrast, the birds that are present only in one habitat are those that tend to have special diet, narrow ranges of tolerable environmental conditions and use specialized microhabitat that are not available at the adjacent site (Lindell *et al.*, 2004).

It is likely that a number of other factors contribute to the differences in species richness for different studies due to different location (peat versus mineral soil), seasons and years (related to availability of food resources related to climate), age of oil palm, size and quality of surrounding habitat and effort put into sampling. When compared with other studies at peat swamp forest using the same method, this study recorded the lower species

number compared to peat swamp forest next to the Universiti Malaysia Sarawak (67 species) but higher when compared to the peat swamp forest at Loagan Bunut National Park (18 species) due to less effort in this site. Good representation in family Timalidae at adjacent peat swamp forest in this study is similar to the findings by Rahman and Tuen (2006) at Kota Samarahan and Laman *et al.* (2006) at Logan Bunut National Park. As compared to other studies at oil palm plantation on mineral soil using the same method, this study recorded higher species number compared to Azman *et al.* (2011) and Gouk (2009). The commonness of family Pycnonotidae in oil palm plantation is similar to the findings by Gouk (2009), Azman *et al.* (2011) and Cagod and Nuñeza (2012).

Table 15. Total number of species, families and individuals of bird and total efforts of sampling recorded by Gouk, 2009 and this study at neighbouring forest (F) and oil palm plantation (OP)

	Current Study, 2013		Gouk, 2009	
	F	OP (DFM)	F	OP (BOPE)
Number of Species	31	30	17	8
Number of families	18	18	10	7
Number of Individual	150	184	36	14
Sampling Period, days	34	34	11	11
Total efforts	6120	6120	714	705
Species Diversity, H'	4.360	3.745	1.116	0.845
Captured Rate,	2.45	2.94	5.04	1.99

Similar study in oil palm plantation and neighbouring forest on mineral soil was conducted by Gouk (2009) at Bratak oil palm estate (BOPE), Bau, Sarawak (Table 15) through mist-netting method. Comparatively, the number of bird species recorded in this study (oil palm plantation= 30 species; adjacent peat swamp forest= 31 species) is relatively higher than reported by Gouk (2009) where only 17 species of birds were caught in adjacent forest and

eight species in oil palm estate. Even though avifauna species richness is lower in forest on mineral soil than forest in peat swamp forest, capture rate was calculated to be higher on mineral soil than peat swamp.

According to Gaither (1994) avifauna species richness in forest on mineral soil and forest on peat swamp forest have always been different where peat swamp forests have generally less species compared to forest on mineral soil. While these studies are not comparable because the forest ecosystem, sampling period, captured rate and total efforts were different, both studies show similar trend that species richness and diversity index was higher in the adjacent forest than in the oil palm plantation. This might be due to oil palm plantation offering less food (fruit and insect) resources and low security from predator attack compared to peat swamp forest. Besides that, the data can show what bird species will use oil palm estate as their alternative habitat at different sites. Out of 30 species recorded at DFM, a total of six species of birds recorded in BOPE was also caught in DFM; Brown-throated Sunbird, Bold Striped-tit Babbler, Olive-winged Bulbul, Rufous-backed Kingfisher, Rufous-tailed Tailorbird and Oriental Magpie Robin. The dominant species captured in BOPE was Olive-winged Bulbul, while in this study Yellow-vented Bulbul was the successful bird which dominated DFM. Even though dominant species at these two plantations are different, both of these species belong to the same family Pycnonotidae.

The location of CMC between DFM and Tradewinds Lingga I Estate (refer to Figure 4) meant that CMC is a fragmented forest. At the present time, CMC is probably a refugia habitat for wildlife that used to live in the forest that has been converted to oil palm estate. This proposition may have been supported in this study where there is significantly high

bird species diversity in CMC. If indeed birds moved into CMC from DFM, such movement would have occurred during the developmental phase. By the time this study was carried out the oil palms were at least seven years old (planted in 2004) and whatever movement that had occurred during development phased has stabilised this was supported in this study where the site closer to each other will have higher shared species (CMC 200 m and DFM 200 m: 11 shared species) while the sites further away from each other will have lower shared species (CMC 500 m and DFM 500 m: 2 shared species).

Edge effect is defined as changes that occur at the abrupt transition between adjacent habitats resulting from the juxtaposition of contrasting ecosystems on either side of the discontinuity (Sammalisto, 1957). Boundary site is a transition zone between adjacent ecological systems (forest and plantation) which have a set of characteristics uniquely called ecotone (Holland, 1988). It plays an important role for birds that prefer both habitats as for foraging and sleeping activities. It contains increased biodiversity since it attracts species that are able to exploit both sides of the discontinuity in addition to those species characteristic of either side (Clapham, 1973). The presence of species of bird that are able to exploit both or either side are influenced by food specialization and habitat association (include humidity, light intensity and temperature) (Maina, 2012).

In this study, forest bird species are being reduced in number as we move from inside the peat swamp forest into oil palm plantation. In contrast the total species and individuals of garden birds decreased as we moved from oil palm plantation into forest. Forest birds use the oil palm plantation up to 500 m from the boundary while a garden bird does not use the peat forest at all. This indicate that forest birds feel threatened and becoming rare as we move from inside the peat swamp forest into the centre of the oil palm plantation. In this

case the threat is due to greater human disturbance from plantation activities such as machinery, vehicle and vocal (Wang *et al.*, 2014). Hence, garden birds are less affected by human disturbance than forest birds.

5.2 Species of high conservation value

In this study, all the birds that belong to families from Alcedinidae (kingfishers), Picidae (woodpeckers) and Strigidae (owls) are protected under local law, Sarawak Wild Life Protection Ordinance, 1998. Besides that, three and five species of near threatened birds listed under IUCN Red List of Threatened Species 2013 were recorded in DFM and CMC, respectively. Even though occurrence of protected or near threatened species of birds is less in oil palm plantation than adjacent peat swamp forest, however all birds still play important ecological roles in oil palm plantation and nearby forest. Therefore plantation management need to maintain ground layer vegetation, canopy pruning and establishment of native fruit tree and promotes the retention of natural or secondary forest patches within and surrounding oil palm areas for biodiversity-friendly plantations as well as for oil palm yield (Azhar *et al.*, 2013).

5.3 Feeding guild in oil palm plantation and adjacent peat swamp forest

In this study, all recorded birds were divided into five feeding guilds. According to Blake (1983) feeding guild composition reflects the types of food that are available in that habitat. Differences in feeding guilds are influenced by land use practices (Azhar *et al.,* 2013). The main factors affecting the distribution of bird feeding guilds in the plantation are vegetation structure, availability of food sources and shelter (Zakaria, 2010).

Insects and fruiting plant survey was carried out along line transects in DFM and CMC to investigate types of food that are available in that habitat. These transects were located at where the mist-nets were established. From this survey, insects were the most abundance available food that can be found every sampling period at both sites than fruiting plant. This result supported the hypothesis that high abundance of insect in both sites attracts species of insectivorous birds to both habitats. The most abundant insect in both habitats was Hymenopterans from the family Formicidae which is similar to the findings by Turner and Foster (2009) and Bawa *et al.* (2011). This insect family is very important to oil palm plantation, whereby besides aiding in decomposition, pollination and preying on other pests, they also act as food resources for predators such as birds (Turner and Foster, 2009). Insects are one of the major prey consumed by birds in oil palm plantation (Chennon and Susanto, 2006; Koh 2008).

Melastoma sp. is the only shrub plant species that has been recorded to bear fruit in this plantation. In the plantation practice, this shrub is classified as noxious weed that has to be controlled to reduce competition with the oil palm for nutrient, moisture and light (Barnes and Luz 1990). Plant diversity in oil palm plantation is restricted to several adaptable natural ground cover or local vegetation such as ground and epiphytic ferns, *Nephrolepis*

biserrata (Koh, 2008). In adjacent peat swamp forest, fruit plant was abundant and diverse as compared to oil palm plantation. *Endiandra coriacea*, *Medinilia* sp., *Baccaurea bracteata*, *Elaocarpus* sp., *Ilex cymosa*, *Lithocarpus* sp. and *Embelia ribes* were the plants recorded to bear fruit from March to July. The availability of all of these resources (insects and fruit) contributes to the presence of different feeding guild of birds in both sites.

Azhar *et al.* (2013) reported that feeding guild in oil palm plantation is fewer compared to logged-over peat swamp forest. The results of the current study however showed that adjacent peat swamp forest supported similar feeding guilds of understory birds as oil palm landscapes except for frugivores. Frugivorous birds were hard to capture using mist-nets because most of them were not understorey birds (Zakaria *et al*., 2002). The mist-netting method used in this study focused on understorey birds that fly between 0.2 m to 3 m from the ground (Rahman and Tuen, 2009).

More than half of the total species of understory birds recorded in both sampling sites are insectivores such as babblers, birds that use mainly the understorey of the forest, and finding is different from that of Gouk (2009) and Azman *et al.* (2011). This might be due to peat swamp forest providing fewer fruits to birds compared to mixed forest (Laman *et al*., 2006) hence the available food resource for birds in peat swamp ecosystems is insect (Gaither, 2004). However higher diversity and abundance of omnivores birds such as bulbuls was recorded in DFM than CMC and this is similar to the finding of Azhar *et al.* (2013). Omnivorous birds depend more on ground-layer vegetation rather than native trees (Azhar *et al.*, 2013). Granivorous birds were abundant in CMC than in oil palm plantation due to existance of seed bearing grasses and reeds along the road to a tower inside the peat

swamp forest. Besides that, carnivorous birds were also abundant in CMC where most of them are from family Alcedinidae which feeds on invertebrates and small vertebrates.

5.4 Direction and frequency of birds hit the boundary nets

The direction and frequency of bird crossing between the two habitats (oil palm plantation and adjacent forest) showed the direction of their destination. The result showed that more birds hit the boundary net from the oil palm side to forest suggesting that the peat swamp forest is a preferred destination for the bird and this finding is similar to Gouk (2009). This result might be due to adjacent forest providing greater habitat complexity and food resources (Azhar *et al.*, 2013).

Alternatively, another explanation for this data is shown in the diagram below (Figure 19). This figure shows that the boundary nets were approximately the same height as the oil palm canopy. Birds flying from oil palm plantation towards the forest have a greater chance of hitting the net than those from the forest canopy which were much higher than the nets. Birds that fly from the forest canopy are more likely to cross into the oil palm plantation at height well above the highest net shelf thereby not hitting the net from the forest side. This suggests that this particular bird must have returned to the oil palm plantation via a different route or from above the net line. This is illustrated by a Pacific Swallow that was first captured flying from oil palm to forest in the morning and later in the day the same individual was recaptured flying in the same direction. This seems to suggest that some birds did cross the boundary net from the forest to the plantation via a different route, either above the net or via the end of the net line.

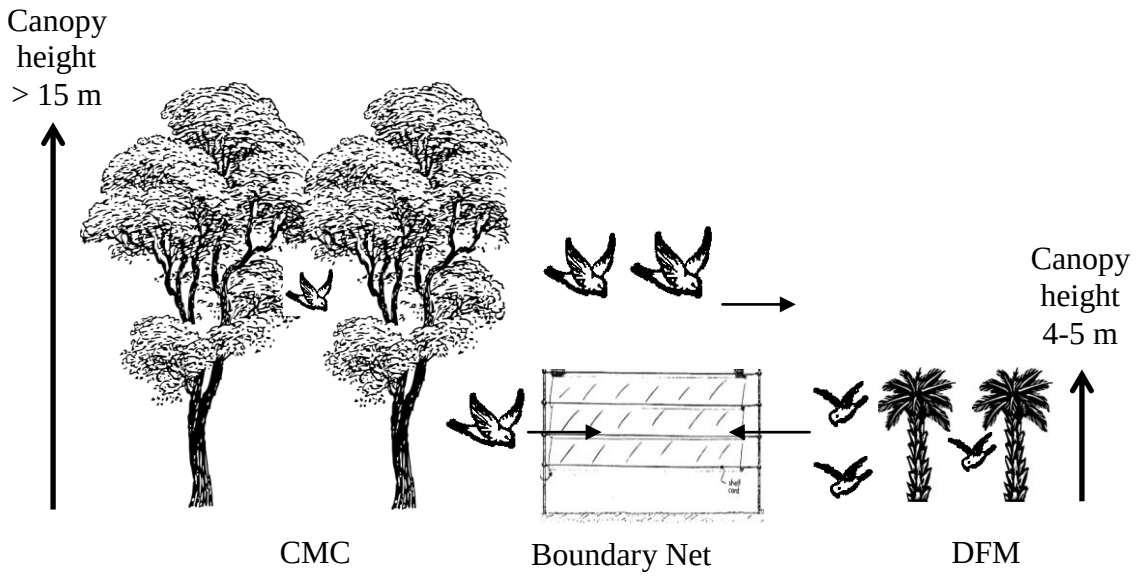


Figure 19. Flying direction of bird at the boundary side.

Besides that, the capture rate of bird at the boundary nets is higher in the morning and late afternoon and this result was supported by studies conducted by Grue *et al.*, (1981) and Robbins (1981). This finding could be interpreted as the need to replenish their energy after the long night sleep, so they were hungry when they wake up in the morning. It could also coincide with peak activity of prey item (Jayatilaka *et al.*, 2010). However in the middle of the day the capture rate of the bird was low and this finding is similar with study carried out by Karr (1979). This is due to weather and time of day which affects avian activity and net visibility (Keyes and Grue, 1982). The normal body temperature of passerine bird is higher, at 40-41^{o}C (Schmidt-Nielsen, 1997) and hence is expected to be more affected by the higher midday temperature. To avoid over heating birds are expected to move less during midday and seek cooler shady places to rest.

5.5 Yellow-vented Bulbul and its diet in oil palm plantation

The Yellow-vented Bulbul is the commonest of all bulbuls and best-known garden bird in Malaysia (Davison and Chew, 2008). This common resident bird can be found in almost all habitats, except in the deep forest, starting from mangrove to secondary forest and from rural to urban areas (Wee, 2009). The success of this bird in almost all habitats is due to their wide ranging diet of both plants and animals (Tan, 2001). This bulbul feed on flowers, nectar, fruits, insects and even carrion (Ward, 1969; Fishpool and Tobias, 2005 and Wells, 2007). In plantation, foraging height of this species is usually in the canopy and the lower strata (Chennon and Susanto, 2006; Myers, 2009; Azman *et al.*, 2011). Now, they have successfully adapted themselves to become one of the abundant birds in cultivated areas such as oil palm plantation (Amit *et al*., 2011; Azman, *et al.*, 2011) and it is considered to provide an ecosystem service as it feeds on insects, usually the leaf eating pests of oil palm (Chenon and Susanto, 2006). The conversion of forest areas to agricultural areas (oil palm plantation) may cause the number of all bird species to decrease (Waltert *et al.*, 2004) and increasing in the number of adaptable or dominant species (Aratrakorn *et al*., 2006). Forests offers more niches, structure is more complex, and plant species more diversified compared to agriculture areas (Azman *et al.*, 2011; Fitzherbert 2008; Koh and Wilcove 2008; Fujioka and Yosida 2001). In this study, the Yellow-vented Bulbul was abundant in February due to the breeding season for this species, being early in the year between January to March (Myers, 2009) where they actively go out to search for food to feed the nestlings. However, in November, less number of this species was captured due to the rainy season at the end of the year. The capture rates of birds decreased during the rainy day because the birds seldom go out to search for food at that time (Tuen *et al*., 2006; Gouk, 2009).

In the study of the diet of birds, there are some factors that should be included in explanation; foraging height, use of plant species, habitat selection and competition (MacArthur, 1958; Morse, 1968; Perrins and Birkhead, 1983). Hence, the presence of prey items in the stomach and availability of insect diversity in the environment can be used to determine the diet selection of birds at different habitat. In this study, this bird seems to exclusively select as their food Coleopterans from family Curculionidae (the pollinating weevil, *Elaeidobius kamerunicus*), Scolytidae and (Staphylinidae). This finding is similar to Chennon and Susanto (2006) who conducted their study at Bah Jambi and Bukit Maradja, Indonesia. Besides Yellow-vented Bulbul, species of bird like Ashy Tailorbird, Oriental Magpie Robin and Long-tailed Shrike were also reported by Chennon and Susanto (2006) to feed on insect from family Curculionidae. *Elaeidobius kamerunicus* is one of the most important weevils that pollinate oil palm. This species was introduced into Malaysia to overcome the inconsistencies of oil palm pollination (Syed *et al.*, 1982). The introduction of this species increased pollination and fruit production from 20% to 30% (Syed, 1982 and Basri *et al.*, 1983). Now, this seemingly exclusive diet of the bulbul towards the pollinating weevil raises a new concern to the oil palm planters; whether the abundance of this bird species contributes to the low fruit set, as reported by some oil palm plantations in peat areas. Further study is certainly required to verify this phenomenon.

While for Orders Diptera and Hemiptera, Yellow-vented Bulbul opportunistically select prey from these Orders based on abundance. Yellow-vented Bulbul tried to avoid feeding on Hymenoptera in the environment while it completely avoids feeding on Orders Odonata, Orthoptera, Dictyoptera and Lepidoptera in the environment. In this study, these Orders are present in the environment but was absent in their gut. However this finding is different from Chennon and Susanto (2006), where insects from Orders Lepidoptera and

Orthoptera were found in the gut content of this species. Based on their stomach content, Yellow-vented Bulbul also feeds on oil palm fruitlets (some palm fruit fibres were found in their stomach sample content), a result which was not reported by Chenon and Susanto (2006).

CHAPTER 6

CONCLUSIONS

Using mist-net method, 30 avifauna species were recorded in oil palm plantation and 31 species were recorded in adjacent peat swamp forest. However bird assemblages in oil palm plantation was different from peat swamp forest with only 13 species common to both ecosystem. Shannon diversity index further indicated that diversity was significantly higher in peat swamp forest as compared to oil palm plantation. This result might be due to peat swamp forest have suitable microclimate, complex forest structure, sufficient food source, less competition and predation. The number of forest bird species was also lower in oil palm plantation compared to peat swamp forest while garden birds were present only in oil palm plantation.

There was significantly more birds hitting the boundary net from the oil palm side suggesting that the adjacent peat swamp forest is a preferred destination for the understorey bird due probably to greater habitat complexity providing diverse food resources and protection from predators. The frequency of bird hitting the boundary net was significantly higher in the morning than in midday and afternoon.

The oil palm plantation provides food resources such as insects and fruits for the Yellow-vented Bulbul. In this habitat, this bird actively select small beetles (specifically from family Curculionidae, Staphylinidae, and Scolytidae) as their prey followed by leafhoppers (Cicadellidae), mosquito (Culicidae), ants (Formicidae) and bugs and these foods were the resources that sustain the abundance of this bird in oil palm plantation. This species completely avoids feeding on insects from the Order Odonata, Orthoptera, Dictyoptera and Lepidoptera.

CHAPTER 7

RECOMMENDATIONS

In the interest of study on ecology of birds in oil palm plantation, the following general recommendations are proposed which could help to increase scientific understanding of how bird diversity enhance the value of oil palm plantation. These recommendations are based on results in this study and references from relevant literature.

More studies should be conducted in oil palm estate and smallholding in the country through mist-netting method and point count method so that we can have a comprehensive baseline data on bird inventory in oil palm plantation. This study should investigate factors such as different cover crop establishment in oil palm plantation so that we have some idea which cover crop can sustain bird diversity in oil palm plantation.

In addition, bird diversity in oil palm plantation should be compared with other commodities such as rubber, tobacco, pepper, cocoa and kenaf or other oil producers such as soy bean, sunflower and corn in order to investigate the impact of different agricultural practices on bird diversity.

In order to establish the important role played by ecotones, more nets should be set up along the boundary between oil palm plantation and adjacent forest in order to make a conclusion regarding the relative value of oil palm plantation and adjacent forest as habitat for birds.

Oil palm plantation seems to provide sufficient food resources for Yellow-vented Bulbul to continue their survival. However affinity towards predating the oil palm pollinating weevil is causing some concern as it would affect the population of the pollinating weevil and eventually the oil palm yield. In order to get a good data, further study on weevil population in oil palm plantation in relation to weevil number consumed by Yellow-vented Bulbul in their diet should be carried out.

Other studies should focus on movement and home range of birds between oil palm plantation and forest via placement of nets deeper into the plantation and forest to determine the extent of edge effect on bird community.

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Appendix 1. Permit from Forestry Department of Sarawak (2010-2011)

IBU PEJABAT JABATAN HUTAN,
WISMA SUMBER ALAM,
JALAN STADIUM, PETRA JAYA,
93660 KUCHING,
SARAWAK

Kawat : Perhutanan, Kuching
Telefon Am: 082-319102, 319103
Telefeks : 082-441377
Telek :

Ruj. Tuan :
Ruj. Kami : NCCD.907.4.4(V)- 216
Tarikh : 27 September 2010

Ms Ella ak Micheal Dosi
Malaysian Palm Oil Board (MPOB)
MPOB Sessang,
Kompleks MPOB,
Jalan Saratok/Roban Lama,
Peti Surat 69,
95407 Saratok

Dear Sir,

Permission To Conduct Research on Biological Resources – Permit No. NCCD.907.4.4(V)-215 and Park Permit No. 115/2010

The application for the above subject matter refers.

2. Enclosed herewith are the permission and approval for you to conduct research.

3. Please liaise with Sarawak Forestry Corporation (SFC) who is your counterpart for this research.

"BERSATU BERUSAHA BERBAKTI"
"AN HONOUR TO SERVE"

Yours faithfully,

(DATU HAJLLEN TALIF SALLEH)
Controller of Wildlife/
Controller of National Parks and Nature Reserves
Forest Department
SARAWAK

c.c. State Secrectary, Sarawak
(Attn.: Director, State Planning Unit)

.... Chief Executive Officer
Sarawak Biodiversity Centre

Director, Immigration Department*

Chief Executive Officer
Sarawak Forestry Corporation
(Attn: **Mr. Wilfred Landong**)

Assistant Director Of Forest,
Research and Development, Kota Sentosa.

IBU PEJABAT JABATAN PERHUTANAN,
WISMA SUMBER ALAM,
JALAN STADIUM,
PETRA JAYA,
93660 KUCHING,
SARAWAK.

Kawat : *Perhutanan, Kuching*
Telefon Am : *082-319102/319103*
Telefeks : *082-441377*
E-mail :

Ruj. Tuan :
Ruj. Kami : NCCD.907.4.4(V)- 215
Tarikh : 27 September 2010

Ms Ella ak Micheal Dosi
Malaysian Palm Oil Board (MPOB)
MPOB Sessang,
Kompleks MPOB,
Jalan Saratok/Roban Lama,
Peti Surat 69,
95407 Saratok

Dear Sir,

Permission to conduct Research on Biological Resources/Collect Samples of Biological Resources for Research-: Effects of Conservation of Peat Swamp Forest to Oil Palm Plantation on Fauna Biodiversity

I refer to your application letter dated 14th July 2010. Permission is hereby granted for you to conduct research and to collect samples of the biological resources stated below:

2. The biological resource(s) is specified herein.

Species		Location	Quantity
Scientific Name	**Type of Organism**		
	bird, insect, hepertofauna and mammals	Maludam National Park Betong Division	At least two of specimens per taxa
	Fish		five specimens per taxa per sampling station

3. The permission is valid for **one (1) year**, effective from **01st October 2010 – 30th September 2011.**

4. The permission is granted on a personal to holder basis and shall not be assigned. The holder must produce this letter for inspection when called upon by any member of the issuing authority or any other enforcement agencies.

5. The permission is conditional upon the fulfillment of any requirement under the Immigration Act 1959/63 (Act 155) and the Immigration Regulations 1963, if any.*

6. The permission is issued on the expressed condition that the holder shall not conduct research to determine their medicinal, pharmaceutical, therapeutic, nutritional or agricultural properties of the biological resources collected and ensures that the same is not done by others.

7. The collection of samples of biological resource other than specified in Para. 2 shall constitute a breach. The permission may be summarily withdrawn if the holder is in breach of the condition herein contained or shall contravene any other written laws governing the collection and utilization of the biological resources taken pursuant to the permission granted.

8. No specimens collected shall be exchanged with any other parties without prior written permission or consent from the issuing authority.

9. The authority is at liberty to assign one or more local counterpart to accompany the holder and to participate in research and in the collection of the biological resources. The holder is to deposit a duplicate copy/a voucher of the biological resources collected with the authority.

10. The issuing authority and / or the State Government of Sarawak shall not be liable for any injuries or loss of life caused or arising out of or in any way connected with the conduct of the research and the collection of the biological specimens or during the duration of stay in Sarawak for the purpose of the research or collection or while travelling to and from the research or collecting site.

11. The holder shall bear all the expenses incurred on the research conducted unless otherwise stated.

12. The holder shall brief and debrief the member staff of issuing authority in charge of the area, where the research is to be conducted, and prior to and before leaving the research areas and also a final briefing on the research finding shall be given to the authority before leaving Sarawak at the end of the research.

13. The holder shall notify the issuing authority of any previously undescribed species found and the proposed name.

14. The holder shall submit three (3) copies of brief summary of research finding and a preliminary report including data and images either in English or Bahasa Malaysia at the completion of fieldwork to the issuing authority. The holder shall also submit three (3) copies of research report or publication to the issuing authority upon completion of research.

15. The holder shall comply with all the written laws, rules and regulations made thereunder governing the removal of the biological resources from the state of Sarawak.

16. This permission is not an export permit. The holder, who intends to export the collected specimens, must apply for an export permit from the relevant authority.

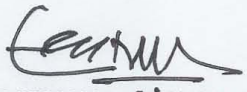
17. The materials collected should neither be commercialized nor transferred to a third party without prior written permission or consent from the issuing authority.

"Addressing Global Demands and Expectations in Forestry"

'BERSATU BERUSAHA BERBAKTI'

"AN HONOUR TO SERVE"

Yours faithfully,



(DATU HAJI LÈN TALIF SALLEH)
Director of Forests/
Controller of Wild Life/
Controller of National Parks & Nature Reserves
Forests Department
SARAWAK

c.c. State Secretary, Sarawak
(Attn.: Director, State Planning Unit)

..... Chief Operating Officer
Sarawak Biodiversity Centre

..... Director, Immigration Department *

General Manager
Sarawak Forestry Corporation
(Attn:**Mr. Wilfred Landong**)

Assistant Director Of Forest
Research and Development, Kota Santosa.

* Delete where not applicable

FIRST SCHEDULE

THE NATIONAL PARKS AND NATURE RESERVES REGULATIONS 1999
FORM OF PERMIT
(Not Transferable)
(Regulation 5)

Permit No: **115/2010**

Permission is hereby given to **Ms Ella ak Micheal Dosi** Malaysian Palm Oil Board (MPOB) MPOB Sessang, NRIC/Passport No: **871123526170**

And the following persons, namely ---

1. NRIC/Passport No:

to enter **Maludam National Park** in Betong Division, Sarawak and to:-

(a) ~~exercise a subsisting right/privilege namely~~ .....
(b) ~~conduct a special activity, namely~~ .....
(c) conduct a research activity, namely Effects of Conservation of Peat Swamp Forest to Oil Palm Plantation on Fauna Biodiversity
(d) ~~conduct an expedition, namely~~ .....
(e) ~~conduct a filming work, namely~~ .....

Subject to the agreement/ terms and special conditions* as prescribed by the Controller.

Date of Issue: **27.09.2010**
Valid Until (date): **30.09.2011**

Fees paid (RM): Waived

Signature: .....

IBU PEJABAT JABATAN HUTAN SARAWAK

Name: **DATU HAJI LEN TALIF SALLEH**

Official Stamp: .....
Controller of National Parks & Nature Reserves

N.R.1. This permit shall be returned to the Controller or any authorized Park Officer upon its expiration, cancellation or withdrawal.

2. This permit must be produced for inspection at any time on demand by the Controller or any authorized Park Officer.
(Special conditions attached)

**Delete wherever inapplicable*

IBU PEJABAT JABATAN HUTAN,
WISMA SUMBER ALAM,
JALAN STADIUM, PETRA JAYA,
93660 KUCHING,
SARAWAK

Kawat :Perhutanan, Kuching
Telefon Am :082-319102, 319103
Telefeks :082-441702

Ruj. Tuan :

Ruj. Kami : NCCD.907.4.4(Jld.7)-145

Tarikh : 23rd May 2012

Ella Michael Dosi
Malaysian Palm Oil Board,
MPOB Sessang Research Station,
Kompleks MPOB, Jalan Rotan Lama,
P.O. BOX 99 95400
Serian, Sarawak

Dear Miss,

Permission to Conduct Research on Biological Resources – Permit No. NCCD.907.4.4(Bd.7)-145 and Park permit No.131/2012

The application for the above subject matter refers.

2. Enclosed herewith are the approvals from Controller of Wildlife-National Parks & Nature Reserves for you to conduct research on "Effects of Conversion of Peat Swamp Forest to Oil Palm Plantation on Fauna Biodiversity".

3. Please liaise with Sarawak Forestry Corporation Sdn. Bhd. (SFCSB) and Research, Development and Innovation Division of the Forest Department, Sarawak, who may provide you with counterpart.

Thank you.

'BERSATU BERUSAHA BERBAKTI'

'AN HONOUR TO SERVE'

Yours faithfully,

(HAJI ALI BIN YUSOP)
Controller of Wild Life of Forests/
Controller of National Parks & Nature Reserves
Forests Department
SARAWAK

cc. State Secretary, Sarawak
(Attn.: Director, State Planning Unit)

Director, Immigration Department

Chief Executive Officer
Sarawak Forestry Corporation

Assistant Director Of Forest
Research, Development and Innovation Area Samling

IBU PEJABAT JABATAN HUTAN,
WISMA SUMBER ALAM,
JALAN STADIUM, PETRA JAYA,
93660 KUCHING,
SARAWAK

Kawat :Perhutanan, Kuching
Telefon Am :082-319102, 319103
Telefeks :082-441702

Ruj. Tuan :

Ruj. Kami : NCCD.907.4.4(JH 7) 145

Tarikh : 23rd May 2012

Ella Michael Dosi
Bettycopa Amit
Malaysian Palm Oil Board
MPOB Sessang Research Station
Kompleks MPOB, Jalan Roban Lama,
P.O. BOX 69, 95400
Sarabok, Sarawak

Dear Miss

Permission to conduct Research on Biological Resources/Collect Samples of Biological Resources for Research-: Effects of Conversion of Peat Swamp Forest to Oil Palm Plantation on Fauna Biodiversity.

I refer to your application letter dated 15th May 2012. Permission is hereby granted for you to conduct research and to collect samples of the biological resources stated below:

2. The biological resource(s) is specified herein

Species		Location	Quantity
Scientific Name	Type of Organism		
	Terrestrial fauna Aquatic fauna / water quality	Ourafarm Plantation Proposed Oermel Oeria Plantation Tanjung Baru Forest Maludam National Park	

3. The permission is valid for One (01) year effective from **23rd May 2012 until 22nd May 2012.**

4. The permission is granted on a personal to holder basis and shall not be assigned. The holder must produce this letter for inspection when called upon by any member of the issuing authority or any other enforcement agencies.

5. The permission is conditional upon the fulfilment of any requirement under the Immigration Act 1959/63 (Act 155) and the Immigration Regulations 1963, if any.

6. The permission is issued on the expressed condition that the holder shall not conduct research to determine their medicinal, pharmaceutical, therapeutic, nutritional or agricultural properties of the biological resources collected and ensures that the same is not done by others.

7. The collection of samples of biological resource other than specified in Para. 2 shall constitute a breach. The permission may be summarily withdrawn if the holder is in breach of the condition herein contained or shall contravene any other written laws governing the collection and utilization of the biological resources taken pursuant to the permission granted.

8. No specimens collected shall be exchanged with any other parties without prior written permission or consent from the issuing authority.

9. The authority is at liberty to assign one or more local counterpart to accompany the holder and to participate in research and in the collection of the biological resources.

10. The holder is to deposit a duplicate copy/s voucher of the biological resources collected with the authority.

11. The issuing authority and / or the State Government of Sarawak shall not be liable for any injuries or loss of life caused or arising out of or in any way connected with the conduct of the research and the collection of the biological specimens or during the duration of stay in Sarawak for the purpose of the research or collection or while traveling to and from the research or collecting site.

12. The holder shall bear all the expenses incurred on the research conducted unless otherwise stated.

13. The holder shall brief and debrief the member staff of issuing authority in charge of the area, where the research is to be conducted, and prior to and before leaving the research areas and also a final briefing on the research finding shall be given to the authority before leaving Sarawak or the end of the research.

14. The holder shall notify the issuing authority of any previously undescribed species found and the proposed name.

15. The holder shall submit three (3) copies of brief summary of research finding and a preliminary report including data and images either in English or Bahasa Malaysia at the completion of fieldwork to the issuing authority. The holder shall also submit three (3) copies of research report or publication to the issuing authority upon completion of research.

16. The holder shall comply with all the written laws, rules and regulations made thereunder governing the removal of the biological resources from the state of Sarawak.

17. This permission is not an export permit. The holder who intends to export the collected specimens must apply for an export permit from the relevant authority.

'BERSATU BERUSAHA BERBAKTI'

'AN HONOUR TO SERVE'

Yours faithfully,

(HAJI ALI YUSOP)
Director of Forests/ Controller of Wild Life /
Controller of National Parks & Nature Reserves
Forests Department
SARAWAK

cc State Secretary, Sarawak
(Attn : Director, State Planning Unit)

Director, Immigration Department *

General Manager
Sarawak Forestry Corporation

Assistant Director of Forest
Research , Development & Innovation Division

FIRST SCHEDULE
THE NATIONAL PARKS AND NATURE RESERVES
REGULATIONS 1999
FORM OF PERMIT
(Not Transferable)
(Regulation 5)

Permit No: **131/2012**

Permission is hereby given to **Ella Michael Dosi** of Malaysian Palm Oil Board, MPOB Sessang Research Station, Kompleks MPOB, Jalan Roban Lama, P.O. BOX 69, 95400, Saratok, Sarawak NRIC/Passport No: **871123-13-6170**

And the following persons, namely --

1 **Bettycopa Amit** NRIC/Passport No: **861025-13-5070**

To enter Maludam National Park in Betong Division and to:-

(a) ~~exercise a subsisting right/privilege namely~~ .....
(b) ~~conduct a special activity, namely~~ .....
(c) conduct a research activity, namely Effects of Conversion of Peat Swamp Forest to Oil Palm Plantation on Fauna Biodiversity.
(d) ~~conduct an expedition, namely~~ .....
(e) ~~conduct a filming work, namely~~ .....

Subject to the agreement/ terms and special conditions* as prescribed by the Controller.

Date of Issue: **23. 05. 2012**
Valid Until (date) **22. 05. 2013**

Fees paid (RM): Waived

Signature: .....

Name: **HAJI ALI BIN YUSOP**

FOREST DEPARTMENT HQ SARAWAK

Official Stamp .....
Controller of National Parks & Nature Reserves

N.B.: 1 This permit shall be returned to the Controller or any authorized Park Officer upon its expiration, cancellation or withdrawal.

2 This permit must be produced for inspection at any time on demand by the Controller or any authorized Park Officer.
(Special conditions attached)

*Delete whichever inapplicable

Copy

No. 09993

THE WILD LIFE PROTECTION RULES, 1998

FORM OF LICENCE/PERMIT*

(Not transferable)

Permission is hereby given to BETTYCOPA AMIT

of (address) MPCSB Sessang Research Station, Kompleks MPCSB Jln. Ruban Lama 95400 Semporna

to (act permitted) Use of Mistnets the following wild plants/animals*, namely—

The species: ..... Common name: Birds & Bats

The number: ..... Sex (if known): .....

subject to the Wild Life Protection Ordinance, 1998, any rules made thereunder, and to the following special conditions, namely—

Strictly for research purpose only.

Date of issue: 23.05.2012

Valid to (date): 22.05.2013

Fees RM Waived (paid)

Renewed to .....

Signature: .....

Name of Wild Life Officer: HAJI ALI BIN YUSOP

Designation: Controller of Wild Life

N.B. (1) This *Licence/Permit is to be returned to the Controller or an authorized Wild Life Officer upon its expiration, cancellation or withdrawal.

(2) This *Licence/Permit shall be displayed at a conspicuous place at the above address.

*Strike in appropriate

IBU PEJABAT JABATAN HUTAN
WISMA SUMBER ALAM
JALAN STADIUM
PETRA JAYA
93660 KUCHING
SARAWAK

Kawat: Perhutanan, Kuching
Telefon Am: 082-442180
Telefeks: 082-441377
Teleks:

Ruj. Tuan :

Ruj. Kami : NCCD.907.4.4(Jld.9)-98

Tarikh : 05 July 2013

Ella Michael Dosi
Bettycopa Ak Amit
Malaysian Palm Oil Board (MPOB)
MPOB Sessang Research Station,
Kompleks MPOB, Jalan Roban Lama,
Peti Surat 69,
95400 Saratok

Dear Sir/Madam,

Permission to Conduct Research on Biological Resources – Permit No. NCCD.907.4.4(Jld.9)-97 and Park Permit No 221/2013

The application for the above subject matter refers.

2. Enclosed herewith are the permission and approval for your group to conduct research in Sarawak. Kindly be reminded to comply with rules and regulations as stated in the section 26, 36, 46 of National Parks and Nature Reserves Ordinance,1998 as attached. This approval letter is to be returned to the Controller upon the expiration.

3. Please liaise with Sarawak Forestry Corporation Sdn Bhd (SFCSB) and Research Development and Innovation (RDI) Sarawak Forest Department who are your counterpart for this research.

Thank you.

"BERSATU BERUSAHA BERBAKTI"
"AN HONOUR TO SERVE"

Yours faithfully,

(DATU HAJI ALI YUSOP)
Controller of Wild Life/
Controller of National Parks and Nature Reserves
Forest Department
SARAWAK

c.c. State Secretary, Sarawak, (Attn.: Director, State Planning Unit)

.... Chief Executive Officer, Sarawak Biodiversity Centre **(Attn.: Madam Margarita Naming)**

Director, Immigration Department*

Chief Executive Officer, Sarawak Forestry Corporation **(Attn: Mr. Oswald Braken)**

Assistant Director of Forest, Research Development and Innovation, Kota Santosa

"HUTAN UNTUK KOMUNITI"

IBU PEJABAT JABATAN PERHUTANAN,
WISMA SUMBER ALAM,
JALAN STADIUM,
PETRA JAYA,
93660 KUCHING,
SARAWAK.

Kawat : Perhutanan, Kuching
Telefon Am : 082-319102/319103
Telefeks : 082-441377

Ruj. Tuan :

Ruj. Kami : NCCD.907.4.4(9)-97

Tarikh : 5 July 2013

Ella Michael Dosi
Bettycopa Ak Amit
Malaysian Palm Oil Board (MPOB)
MPOB Sessang Research Station,
Kompleks MPOB, Jalan Roban Lama,
Peti Surat 69,
95400 Saratok

Dear Madam,

Permission to conduct Research on Biological Resources/Collect Samples of Biological Resources for Research-: Effects of Conversion of Peat Swamp Forest to Oil Palm Plantation on Fauna Biodiversity

I refer to your application letter dated 24 June 2013. Permission is hereby granted for you to conduct research and to collect samples of the biological resources stated below:

2. The biological resource(s) is specified herein.

Species		Location	Quantity
Scientific Name	Type of Organism		
Arifauna *Chiroptera*	Macro-invertebrates, Insects Fish Amphibian Reptiles Birds Mammals	Durafarm Oil Palm Plantation Proposed Cermat Ceria Plantation, Tanjung Baru Forest Maludam National Park	Birds-10 heads Mammals-10 heads Water-to be analysed

3. The permission is valid for **one (1) year**, effective from **5 July 2013** until **4 July 2014.**

4. The permission is granted on a personal to holder basis and shall not be assigned. The holder must produce this letter for inspection when called upon by any member of the issuing authority or any other enforcement agencies.

5. The permission is conditional upon the fulfillment of any requirement under the Immigration Act 1959/63 (Act 155) and the Immigration Regulations 1963, if any.*

6. The permission is issued on the expressed condition that the holder shall not conduct research to determine their medicinal, pharmaceutical, therapeutic, nutritional or agricultural properties of the biological resources collected and ensures that the same is not done by others.

7. The collection of samples of biological resource other than specified in Para. 2 shall constitute a breach. The permission may be summarily withdrawn if the holder is in breach of the condition herein contained or shall contravene any other written laws governing the collection and utilization of the biological resources taken pursuant to the permission granted.

8. No specimens collected shall be exchanged with any other parties without prior written permission from the issuing authority.

9. The authority is at liberty to assign one or more local counterpart to accompany the holder and to participate in research and in the collection of the biological resources. The holder is to deposit a duplicate copy/a voucher of the biological resources collected with the authority.

10. The issuing authority and / or the State Government of Sarawak shall not be liable for any injuries or loss of life caused or arising out of or in any way connected with the conduct of the research and the collection of the biological specimens or during the duration of stay in Sarawak for the purpose of the research or collection or while travelling to and from the research or collecting site.

11. The holder shall bear all the expenses incurred on the research conducted unless otherwise stated.

12. The holder shall brief and debrief the member staff of issuing authority in charge of the area, where the research is to be conducted, and prior to and before leaving the research areas and also a final briefing on the research finding shall be given to the authority before leaving Sarawak at the end of the research.

13. The holder shall notify the issuing authority of any previously undescribed species found and the proposed name.

14. The holder shall submit three (3) copies of brief summary of research finding and a preliminary report including data and images either in English or Bahasa Malaysia at the completion of fieldwork to the issuing authority. The holder shall also submit three (3) copies of research report or publication to the issuing authority upon completion of research.

15. The holder shall comply with all the written laws, rules and regulations made thereunder governing the removal of the biological resources from the state of Sarawak.

16. This permission is not an export permit. The holder, who intends to export the collected specimens, must apply for an export permit from the relevant authority.

17. The materials collected should neither be commercialized nor transferred to a third party without prior informed consent or prior consent in writing of the Sarawak Government.

'BERSATU BERUSAHA BERBAKTI'

"AN HONOUR TO SERVE"

Yours faithfully,

(DATU HAJI ALI BIN YUSOP)
Director of Forests/
Controller of Wild Life/
Controller of National Parks & Nature Reserves
Forests Department
SARAWAK

FIRST SCHEDULE
THE NATIONAL PARKS AND NATURE RESERVES
REGULATIONS 1999
FORM OF PERMIT
(Not Transferable)
(Regulation 5)

Permit No: **221/2013**

Permission is hereby given to **Ella Michael Dosi** of **Malaysian Palm Oil Board (MPOB) MPOB Sessang Research Station,Kompleks MPOB, Jalan Roban Lama,Peti Surat 69,95400 Saratok, Sarawak** Passport No.: **761052340**

And the following persons, namely ---

1. Bettycopa Ak Amit NRIC/Passport No: 861025-13-5070

To enter **Maludam National Park** in Sarawak and to:-

(a) ~~exercise a subsisting right/privilege namely~~ .....
(b) ~~conduct a special activity, namely~~ .....
(c) conduct a research activity, namely

Effects of Conversion of Peat Swamp Forest to Oil Palm Plantation on Fauna Biodiversity

(d) ~~conduct an expedition, namely~~ .....
(e) ~~conduct a filming work, namely~~ .....

Subject to the agreement/ terms and special conditions* as prescribed by the Controller.

Date of Issue: **05.07.2013**
Valid Until (date): **04.07.2014**

Fees paid (RM): Waived

Signature: .....

Name: **DATU HAJI ALI YUSOP**

IBU PEJABAT JABATAN HUTAN SARAWAK

Official Stamp: .....
Controller of National Parks & Nature Reserves

N.R.1. This permit shall be returned to the Controller or any authorized Park Officer upon its expiration, cancellation or withdrawal.

2. This permit must be produced for inspection at any time on demand by the Controller or any authorized Park Officer.
(Special conditions attached

**Delete wherever inapplicable.*

No. 14054

THE WILD LIFE PROTECTION RULES, 1998

FORM OF LICENCE/PERMIT*

(Not transferable)

Permission is hereby given to BETTYCOPA ANAK AMIT

of (address) MPOB Research Station Sesang, Kompleks MPOB, Jln. Roban Lama, P.O.Box 69, 95400 Saratok

to (act permitted) Use Mist Nest the following wild plants/animals*, namely—

The species: Aves and Chiroptera Common name: Birds and Bats

The number: ..... Sex (if known): .....

subject to the Wild Life Protection Ordinance, 1998, any rules made thereunder, and to the following special conditions, namely—

~~This Permit is issued strictly for capture bats and birds species for research and~~ teaching purpose only.

Date of issue 22.07.2013

Valid to (date) 21.07.2014

Fees RM Waived (paid)

Renewed to .....

FOREST DEPARTMENT HQ

Signature: .....

Name of Wild Life Officer: DATU HJ. AM BIN YUSOP

Designation: Controller of Wild Life

N.B. (1) This *Licence/Permit is to be returned to the Controller or an authorized Wild Life Officer upon its expiration, cancellation or withdrawal.

(2) This *Licence/Permit shall be displayed at a conspicuous place at the above address.

**Delete as appropriate.*

JD967252—PNMB, Kch.

Appendix 2. Species Diversity for Cermat Ceria Forest Data

```
=========================================================
|          PROGRAM DIVERS Version 1.2                  |
|    This program calculates heterogeneity measures of |
|     species diversity, from species adundance data.  |
|   Simpson"s index, the Shannon-Wiener function,      |
|   and Brillouin"s index are computed, along with     |
|   estimates of evenness.                             |
 | Modified by Charlie Laman (FRST, UNIMAS, August, 2001) |
=========================================================
  PROBLEM LABEL IS:
  ** CERMAT CERIA (MIST-NETTED (BIRD), 2011-2013 data)
   ABUNDANCE DATA, ONE SPECIES PER LINE, LAST DATA, INPUT
     AS 0.0 OR END-OF-FILE. (Maximum is 200 species)
  RAW DATA:
  SPECIES NO.    NO.OF INDIVIDUALS    PROPORTION OR SAMPLE
=========================================================
      1            4.              0.027
      2            6.              0.040
      3            1.              0.007
      4            1.              0.007
      5           23.              0.153
      6            9.              0.060
      7            5.              0.033
      8           14.              0.093
      9           17.              0.113
     10            3.              0.020
     11            1.              0.007
     12            3.              0.020
     13            1.              0.007
     14            7.              0.047
     15            2.              0.013
     16            2.              0.013
     17            7.              0.047
     18            6.              0.040
     19            1.              0.007
     20            1.              0.007
     21            3.              0.020
     22            5.              0.033
     23            1.              0.007
     24            5.              0.033
     25            8.              0.053
     26            4.              0.027
     27            1.              0.007
     28            1.              0.007
     29            2.              0.013
     30            3.              0.020
     31            3.              0.020
```

.....ETC. UP TO 200 SPECIES

O TOTAL NO.OF INDIVIDUALS = 150.

O * SIMPSON DIVERSITY INDEX FOR INFINITE POPULATION (1-D) = 0.933
RECIPROCAL OF SIMPSON DIVERSITY INDEX FOR INFINITE POPULATION (1/D) = 14.980
SIMPSON DIVERSITY INDEX FOR FINITE POPULATION (1-Dhat) = 0.940

* SHANNON-WIENER DIVERSITY = 4.360 BITS PER INDIVIDUAL
NUMBER OF EQUALLY COMMON SPECIES, N(i) = 20.538

O * BRILLOUINOS DIVERSITY (H) = 3.937 BITS PER INDIVIDUAL.

O MAXIMUM POSSIBLE DIVERSITY :
==========

SIMPSON (1-D) = 0.974 EVENNESS = 0.062
SHANNON-WIENER = 4.954 (EVENNESS = 0.880) (H/HMAX)

Appendix 3. Species Diversity for Durafarm Data

```
=========================================================
|          PROGRAM DIVERS Version 1.2                   |
|    This program calculates heterogeneity measures of  |
|     species diversity, from species adundance data.   |
|   Simpson"s index, the Shannon-Wiener function,       |
|   and Brillouin"s index are computed, along with      |
|   estimates of evenness.                              |
| Modified by Charlie Laman (FRST, UNIMAS, August, 2001) |
=========================================================
 PROBLEM LABEL IS:
 ** DURAFARM DATA (BIRDS, 2011-2013 data)
  ABUNDANCE DATA, ONE SPECIES PER LINE, LAST DATA, INPUT
    AS 0.0 OR END-OF-FILE. (Maximum is 200 species)
 RAW DATA:
 SPECIES NO.    NO.OF INDIVIDUALS    PROPORTION OR SAMPLE
=========================================================
     1            4.              0.022
     2            2.              0.011
     3            1.              0.005
     4            1.              0.005
     5            2.              0.011
     6           17.              0.092
     7            4.              0.022
     8           56.              0.304
     9            3.              0.016
    10            1.              0.005
    11            1.              0.005
    12            1.              0.005
    13            1.              0.005
    14            7.              0.038
    15            4.              0.022
    16           18.              0.098
    17           16.              0.087
    18            8.              0.043
    19            1.              0.005
    20            1.              0.005
    21           12.              0.065
    22            3.              0.016
    23            2.              0.011
    24            9.              0.049
    25            3.              0.016
    26            1.              0.005
    27            1.              0.005
    28            1.              0.005
    29            1.              0.005
    30            2.              0.011
     .....ETC. UP TO  200   SPECIES
```

O TOTAL NO.OF INDIVIDUALS = 184.
O * SIMPSON DIVERSITY INDEX FOR INFINITE POPULATION (1-D) = 0.869
RECIPROCAL OF SIMPSON DIVERSITY INDEX FOR INFINITE POPULATION (1/D) = 7.615
SIMPSON DIVERSITY INDEX FOR FINITE POPULATION (1-Dhat) = 0.873
* SHANNON-WIENER DIVERSITY = 3.745 BITS PER INDIVIDUAL
NUMBER OF EQUALLY COMMON SPECIES, N(i) = 13.409
O * BRILLOUINOS DIVERSITY (H) = 3.423 BITS PER INDIVIDUAL.
O MAXIMUM POSSIBLE DIVERSITY :
==========
SIMPSON (1-D) = 0.972 EVENNESS = 0.130
SHANNON-WIENER = 4.907 (EVENNESS = 0.763) (H/HMAX)

Appendix 4. Calculation of Zar's Modified t-test for DFM data and CMC data

	DFM DATA	=B1*LOG(B1)	=B1*(LOG(B1)*LOG(B1
Species1	**4**	2.408239965	1.449904933
Species2	**2**	0.602059991	0.181238117
Species3	**1**	0	0
Species4	**1**	0	0
Species5	**2**	0.602059991	0.181238117
Species6	**17**	20.91763166	25.73807732
Species7	**4**	2.408239965	1.449904933
Species8	**56**	97.89852951	171.1450372
Species9	**3**	1.431363764	0.682934075
Species10	**1**	0	0
Species11	**1**	0	0
Species12	**1**	0	0
Species13	**1**	0	0
Species14	**7**	5.91568628	4.999334881
Species15	**4**	2.408239965	1.449904933
Species16	**18**	22.59490509	28.36276312
Species17	**16**	19.26591972	23.19847892
Species18	**8**	7.224719896	6.524572197
Species19	**1**	0	0
Species20	**1**	0	0
Species21	**12**	12.95017495	13.97558594
Species22	**3**	1.431363764	0.682934075
Species23	**2**	0.602059991	0.181238117
Species24	**9**	8.588182585	8.195208901
Species25	**3**	1.431363764	0.682934075
Species26	**1**	0	0
Species27	**1**	0	0
Species28	**1**	0	0
Species29	**1**	0	0

Species30	**2**	0.602059991	0.181238117
Total	184	209.2828009	289.2625279
Variance			**0.001512964**
	CMC DATA		
Species1	**4**	2.408239965	1.449904933
Species2	**6**	4.668907502	3.633116211
Species3	**1**	0	0
Species4	**1**	0	0
Species5	**23**	31.31974023	42.64896209
Species6	**9**	8.588182585	8.195208901
Species7	**5**	3.494850022	2.442795335
Species8	**14**	16.0457925	18.39053264
Species9	**17**	20.91763166	25.73807732
Species10	**3**	1.431363764	0.682934075
Species11	**1**	0	0
Species12	**3**	1.431363764	0.682934075
Species13	**1**	0	0
Species14	**7**	5.91568628	4.999334881
Species15	**2**	0.602059991	0.181238117
Species16	**2**	0.602059991	0.181238117
Species17	**7**	5.91568628	4.999334881
Species18	**6**	4.668907502	3.633116211
Species19	**1**	0	0
Species20	**1**	0	0
Species21	**3**	1.431363764	0.682934075
Species22	**5**	3.494850022	2.442795335
Species23	**1**	0	0
Species24	**5**	3.494850022	2.442795335
Species25	**8**	7.224719896	6.524572197
Species26	**4**	2.408239965	1.449904933
Species27	**1**	0	0
Species28	**1**	0	0

Species29	**2**	0.602059991	0.181238117
Species30	**3**	1.431363764	0.682934075
Species31	**3**	1.431363764	0.682934075
Total	150	129.5292832	132.9488359
Variance			**0.000937627**
Std. Dev			
(H1-H2)			**0.04950344**
Diversity Index 1		**3.745**	
Diversity Index 2		**4.360**	
t-calculated			**-12.42337905**
V-calculated	6.00539E-06	1.83015E-08	**328.1367091**

Observed	**p =**	**0.000**	**0.000**
p-value		(1-tailed test)	(2-tailed test)

Conclusion:

The p-value of **0.000** **Is** **<** **0.05**

Therefore the value of |t| **Is** **far from 0.**

Therefore there **is a** **significant difference between H'1 and H'2.**

Appendix 5. Species Diversity for DFM 200 m

```
=========================================================

|           PROGRAM DIVERS Version 1.2                |
|    This program calculates heterogeneity measures of  |
|     species diversity, from species adundance data.   |
|   Simpson"s index, the Shannon-Wiener function,       |
|   and Brillouin"s index are computed, along with      |
|   estimates of evenness.                              |
| Modified by Charlie Laman (FRST, UNIMAS, August, 2001) |
 ========================================================
  PROBLEM LABEL IS:
  ** DURAFARM DATA (MIST-NETTED (BIRD-200m), 2011-2013 data)
   ABUNDANCE DATA, ONE SPECIES PER LINE, LAST DATA, INPUT
     AS 0.0 OR END-OF-FILE. (Maximum is 200 species)
  RAW DATA:
  SPECIES NO.    NO.OF INDIVIDUALS    PROPORTION OR SAMPLE
 ========================================================
       1            2.             0.019
       2            1.             0.009
       3            1.             0.009
       4            1.             0.009
       5            1.             0.009
       6            9.             0.085
       7            4.             0.038
       8           31.              0.292
       9            2.             0.019
      10            1.              0.009
      11            1.              0.009
      12            1.              0.009
      13            5.              0.047
      14            3.              0.028
      15           11.              0.104
```

16	9.	0.085
17	1.	0.009
18	6.	0.057
19	1.	0.009
20	3.	0.028
21	3.	0.028
22	2.	0.019
23	4.	0.038
24	1.	0.009
25	1.	0.009
26	1.	0.009

O TOTAL NO.OF INDIVIDUALS = 106.

O * SIMPSON DIVERSITY INDEX FOR INFINITE POPULATION (1-D) = 0.876

RECIPROCAL OF SIMPSON DIVERSITY INDEX FOR INFINITE POPULATION (1/D) = 8.095

SIMPSON DIVERSITY INDEX FOR FINITE POPULATION (1-Dhat) = 0.885

* SHANNON-WIENER DIVERSITY = 3.784 BITS PER INDIVIDUAL

NUMBER OF EQUALLY COMMON SPECIES, N(i) = 13.773

O * BRILLOUINOS DIVERSITY (H) = 3.337 BITS PER INDIVIDUAL.

O MAXIMUM POSSIBLE DIVERSITY :

==========

SIMPSON (1-D) = 0.971 EVENNESS = 0.119

SHANNON-WIENER = 4.700 (EVENNESS = 0.805) (H/HMAX)

Appendix 6. Species Diversity for DFM 500 m

```
 ==========================================================
|           PROGRAM DIVERS Version 1.2                     |
|    This program calculates heterogeneity measures of     |
|     species diversity, from species adundance data.       |
|   Simpson"s index, the Shannon-Wiener function,           |
|   and Brillouin"s index are computed, along with          |
|   estimates of evenness.                                  |
| Modified by Charlie Laman (FRST, UNIMAS, August, 2001)    |
 ==========================================================
  PROBLEM LABEL IS:
  ** DURAFARM DATA (MIST-NETTED (BIRD-500m), 2011-2013 data)

  ABUNDANCE DATA, ONE SPECIES PER LINE, LAST DATA, INPUT
     AS 0.0 OR END-OF-FILE. (Maximum is 200 species)

  RAW DATA:
  SPECIES NO.    NO.OF INDIVIDUALS    PROPORTION OR SAMPLE
 ==========================================================
       1            2.              0.025
       2            1.              0.013
       3            1.              0.013
       4            8.              0.101
       5           25.              0.316
       6            1.              0.013
       7            1.              0.013
       8            2.              0.025
       9            1.              0.013
      10            7.              0.089
      11            7.              0.089
      12            2.              0.025
      13            1.              0.013
      14            9.              0.114
      15            5.              0.063
      16            2.              0.025
      17            1.              0.013
      18            1.              0.013
      19            2.              0.025
       .....ETC. UP TO  200   SPECIES
O       TOTAL NO.OF INDIVIDUALS =     79.

O  * SIMPSON DIVERSITY INDEX FOR INFINITE POPULATION (1-D)  =   0.852
     RECIPROCAL OF SIMPSON DIVERSITY INDEX FOR INFINITE
     POPULATION (1/D)                                  =   6.776
     SIMPSON DIVERSITY INDEX FOR FINITE POPULATION (1-Dhat) =   0.863

   * SHANNON-WIENER DIVERSITY =   3.398     BITS PER INDIVIDUAL
     NUMBER OF EQUALLY COMMON SPECIES, N(i) =  10.543
```

O * BRILLOUINOS DIVERSITY (H) = 2.969 BITS PER INDIVIDUAL.

O MAXIMUM POSSIBLE DIVERSITY :
==========

SIMPSON (1-D) = 0.959 EVENNESS = 0.142

SHANNON-WIENER = 4.248 (EVENNESS = 0.800) (H/HMAX)

Appendix 7. Species Diversity for CMC 200 m

```
 ==========================================================
 |          PROGRAM DIVERS Version 1.2                    |
 |    This program calculates heterogeneity measures of   |
 |     species diversity, from species adundance data.    |
 |                                    |
 |   Simpson"s index, the Shannon-Wiener function,        |
 |   and Brillouin"s index are computed, along with       |
 |   estimates of evenness.                    |
 |                                    |
 | Modified by Charlie Laman (FRST, UNIMAS, August, 2001) |
 ==========================================================
  PROBLEM LABEL IS:
  ** CERMAT CERIA (MIST-NETTED (BIRD-200m), 2011-2013 data)

  ABUNDANCE DATA, ONE SPECIES PER LINE, LAST DATA, INPUT
     AS 0.0 OR END-OF-FILE. (Maximum is 200 species)

  RAW DATA:
  SPECIES NO.    NO.OF INDIVIDUALS    PROPORTION OR SAMPLE
 ==========================================================
       1             2.              0.030
       2             1.              0.015
       3             6.              0.091
       4             6.              0.091
       5             1.              0.015
       6             8.              0.121
       7            10.              0.152
       8             3.              0.045
       9             1.              0.015
      10             3.              0.045
      11             2.              0.030
      12             1.              0.015
      13             3.              0.045
      14             1.              0.015
      15             1.              0.015
      16             5.              0.076
      17             1.              0.015
      18             2.              0.030
      19             8.              0.121
      20             1.              0.015
       .....ETC. UP TO  200   SPECIES
 O      TOTAL NO.OF INDIVIDUALS =     66.

 O  * SIMPSON DIVERSITY INDEX FOR INFINITE POPULATION (1-D)  =   0.915
     RECIPROCAL OF SIMPSON DIVERSITY INDEX FOR INFINITE
     POPULATION (1/D)                              =  11.710
     SIMPSON DIVERSITY INDEX FOR FINITE POPULATION (1-Dhat) =   0.929
```

* SHANNON-WIENER DIVERSITY = 3.861 BITS PER INDIVIDUAL
NUMBER OF EQUALLY COMMON SPECIES, N(i) = 14.529

O * BRILLOUINOS DIVERSITY (H) = 3.319 BITS PER INDIVIDUAL.

O MAXIMUM POSSIBLE DIVERSITY :
==========

SIMPSON (1-D) = 0.964 EVENNESS = 0.074
SHANNON-WIENER = 4.322 (EVENNESS = 0.893) (H/HMAX)

Appendix 8. Species Diversity for CMC 500 m

```
============================================================
|          PROGRAM DIVERS Version 1.2                      |
|    This program calculates heterogeneity measures of     |
|     species diversity, from species adundance data.       |
|                                        |
|   Simpson"s index, the Shannon-Wiener function,          |
|   and Brillouin"s index are computed, along with         |
|   estimates of evenness.                    |
|                                        |
| Modified by Charlie Laman (FRST, UNIMAS, August, 2001)   |
============================================================
  PROBLEM LABEL IS:
  ** CERMAT CERIA (MIST-NETTED (BIRD-500m), 2011-2013 data)

  ABUNDANCE DATA, ONE SPECIES PER LINE, LAST DATA, INPUT
     AS 0.0 OR END-OF-FILE. (Maximum is 200 species)

  RAW DATA:
  SPECIES NO.    NO.OF INDIVIDUALS    PROPORTION OR SAMPLE
============================================================
       1            2.              0.024
       2            5.              0.060
       3            1.              0.012
       4            1.              0.012
       5           17.              0.202
       6            3.              0.036
       7            4.              0.048
       8            6.              0.071
       9            7.              0.083
      10            3.              0.036
      11            1.              0.012
      12            4.              0.048
      13            1.              0.012
      14            4.              0.048
      15            6.              0.071
      16            3.              0.036
      17            3.              0.036
      18            4.              0.048
      19            1.              0.012
      20            2.              0.024
      21            3.              0.036
      22            3.              0.036
       .....ETC. UP TO  200   SPECIES
O       TOTAL NO.OF INDIVIDUALS =     84.

O  * SIMPSON DIVERSITY INDEX FOR INFINITE POPULATION (1-D)  =   0.920
     RECIPROCAL OF SIMPSON DIVERSITY INDEX FOR INFINITE
```

POPULATION (1/D) = 12.466
SIMPSON DIVERSITY INDEX FOR FINITE POPULATION (1-Dhat) = 0.931

* SHANNON-WIENER DIVERSITY = 4.055 BITS PER INDIVIDUAL
NUMBER OF EQUALLY COMMON SPECIES, N(i) = 16.627

O * BRILLOUINOS DIVERSITY (H) = 3.547 BITS PER INDIVIDUAL.

O MAXIMUM POSSIBLE DIVERSITY :
==========

SIMPSON (1-D) = 0.966 EVENNESS = 0.072

SHANNON-WIENER = 4.459 (EVENNESS = 0.909) (H/HMAX)

Appendix 9. Calculation of Zar's Modified t-test for DFM 200 m data and DFM 500 m data

	DFM 200m	=B1*LOG(B1)	=B1*(LOG(B1)*LOG(B1))
Species1	2	0.602059991	0.181238117
Species2	1	0	0
Species3	1	0	0
Species4	1	0	0
Species5	1	0	0
Species6	9	8.588182585	8.195208901
Species7	4	2.408239965	1.449904933
Species8	31	46.23221251	68.94895076
Species9	2	0.602059991	0.181238117
Species10	1	0	0
Species11	1	0	0
Species12	1	0	0
Species13	5	3.494850022	2.442795335
Species14	3	1.431363764	0.682934075
Species15	11	11.45531954	11.92948597
Species16	9	8.588182585	8.195208901
Species17	6	4.668907502	3.633116211
Species18	1	0	0
Species19	3	1.431363764	0.682934075
Species20	3	1.431363764	0.682934075
Species21	2	0.602059991	0.181238117
Species22	4	2.408239965	1.449904933
Species23	1	0	0
Species24	1	0	0
Species25	1	0	0
Total	105	93.94440594	108.8370925
Variance			**0.002248002**
	DFM 500m		
Species1	2	0.602059991	0.181238117
Species2	1	0	0
Species3	6	4.668907502	3.633116211
Species4	6	4.668907502	3.633116211
Species5	1	0	0
Species6	8	7.224719896	6.524572197
Species7	10	10	10
Species8	3	1.431363764	0.682934075
Species9	1	0	0

Species10	3	1.431363764	0.682934075
Species11	2	0.602059991	0.181238117
Species12	1	0	0
Species13	3	1.431363764	0.682934075
Species14	1	0	0
Species15	1	0	0
Species16	5	3.494850022	2.442795335
Species17	1	0	0
Species18	2	0.602059991	0.181238117
Species19	8	7.224719896	6.524572197
Species20	1	0	0
Total	66	43.38237608	35.35068873
Variance			**0.001569117**
Std. Dev			
(H1-H2)			**0.061782838**

Diversity Index 1	**3.784**
Diversity Index 2	**3.398**

t-calculated			**6.24768964**
V-calculated	1.45704E-05	8.54337E-08	**170.546318**

Observed p-value	**p =**	**0.000** (1-tailed test)	**0.000** (2-tailed test)

Conclusion:

The p-value of **0.000** **Is** **<** **0.05**

Therefore the value of |t| **Is** **far from 0.**

Therefore there **is a** **significant difference between H'1 and H'2.**

Appendix 10. Calculation of Zar's Modified t-test for DFM 200 m data and CMC 200 m data

	DFM 200m	=B1*LOG(B1)	=B1*(LOG(B1)*LOG(B1))
Species1	2	0.602059991	0.181238117
Species2	1	0	0
Species3	1	0	0
Species4	1	0	0
Species5	1	0	0
Species6	9	8.588182585	8.195208901
Species7	4	2.408239965	1.449904933
Species8	31	46.23221251	68.94895076
Species9	2	0.602059991	0.181238117
Species10	1	0	0
Species11	1	0	0
Species12	1	0	0
Species13	5	3.494850022	2.442795335
Species14	3	1.431363764	0.682934075
Species15	11	11.45531954	11.92948597
Species16	9	8.588182585	8.195208901
Species17	6	4.668907502	3.633116211
Species18	1	0	0
Species19	3	1.431363764	0.682934075
Species20	3	1.431363764	0.682934075
Species21	2	0.602059991	0.181238117
Species22	4	2.408239965	1.449904933
Species23	1	0	0
Species24	1	0	0
Species25	1	0	0
Total	105	93.94440594	108.8370925
Variance			**0.002248002**
	CMC 200 m		
Species1	2	0.602059991	0.181238117
Species2	1	0	0
Species3	1	0	0
Species4	8	7.224719896	6.524572197
Species5	25	34.94850022	48.8559067
Species6	1	0	0
Species7	1	0	0
Species8	2	0.602059991	0.181238117
Species9	1	0	0

Species10	7	5.91568628	4.999334881
Species11	7	5.91568628	4.999334881
Species12	2	0.602059991	0.181238117
Species13	1	0	0
Species14	9	8.588182585	8.195208901
Species15	5	3.494850022	2.442795335
Species16	2	0.602059991	0.181238117
Species17	1	0	0
Species18	1	0	0
Species19	2	0.602059991	0.181238117
Species20	1	0	0
Total	80	69.09792524	76.92334347
Variance			**0.002694032**
Std. Dev (H1-H2)			**0.070299599**

Diversity Index 1	**3.784**
Diversity Index 2	**3.861**

t-calculated			**-1.095312077**
V-calculated	2.44237E-05	1.38851E-07	**175.8982498**

Observed p-value	**p =**	**0.275** (1-tailed test)	**0.137** (2-tailed test)	

Conclusion:

The p-value of	**0.275**	**Is**	**>**	**0.05**

Therefore the value of |t| <u>is not</u> far from 0.

Therefore there <u>is no</u> significant difference between H'1 and H'2.

Appendix 11. Calculation of Zar's Modified t-test for DFM 200 m data and CMC 500 m data

	DFM 200m	=B1*LOG(B1)	=B1*(LOG(B1)*LOG(B1))
Species1	2	0.602059991	0.181238117
Species2	1	0	0
Species3	1	0	0
Species4	1	0	0
Species5	1	0	0
Species6	9	8.588182585	8.195208901
Species7	4	2.408239965	1.449904933
Species8	31	46.23221251	68.94895076
Species9	2	0.602059991	0.181238117
Species10	1	0	0
Species11	1	0	0
Species12	1	0	0
Species13	5	3.494850022	2.442795335
Species14	3	1.431363764	0.682934075
Species15	11	11.45531954	11.92948597
Species16	9	8.588182585	8.195208901
Species17	6	4.668907502	3.633116211
Species18	1	0	0
Species19	3	1.431363764	0.682934075
Species20	3	1.431363764	0.682934075
Species21	2	0.602059991	0.181238117
Species22	4	2.408239965	1.449904933
Species23	1	0	0
Species24	1	0	0
Species25	1	0	0
Total	105	93.94440594	108.8370925
Variance			**0.002248002**
	CMC 500 m		
Species1	2	0.602059991	0.181238117
Species2	5	3.494850022	2.442795335
Species3	1	0	0
Species4	1	0	0
Species5	17	20.91763166	25.73807732
Species6	3	1.431363764	0.682934075
Species7	4	2.408239965	1.449904933
Species8	6	4.668907502	3.633116211
Species9	7	5.91568628	4.999334881
Species10	3	1.431363764	0.682934075

Species11	1	0	0
Species12	4	2.408239965	1.449904933
Species13	1	0	0
Species14	4	2.408239965	1.449904933
Species15	6	4.668907502	3.633116211
Species16	3	1.431363764	0.682934075
Species17	3	1.431363764	0.682934075
Species18	4	2.408239965	1.449904933
Species19	1	0	0
Species20	2	0.602059991	0.181238117
Species21	3	1.431363764	0.682934075
Species22	3	1.431363764	0.682934075
Total	84	59.0912454	50.70614037
Variance			**0.001294981**
Std. Dev (H1-H2)			**0.059522963**

Diversity Index 1		**3.784**
Diversity Index 2		**4.055**

t-calculated			**-4.552864736**
V-calculated	1.25527E-05	6.80927E-08	**184.3476629**

Observed p-value	**p =**	**0.000** (1-tailed test)	**0.000** (2-tailed test)

Conclusion:

The p-value of 0.000 Is < 0.05

Therefore the value of |t| Is far from 0.

Therefore there is a significant difference between H'1 and H'2.

Appendix 12. Calculation of Zar's Modified t-test for DFM 500 m data and CMC 200 m data

	DFM 500m	=B1*LOG(B1)	=B1*(LOG(B1)*LOG(B1))
Species1	2	0.602059991	0.181238117
Species2	1	0	0
Species3	6	4.668907502	3.633116211
Species4	6	4.668907502	3.633116211
Species5	1	0	0
Species6	8	7.224719896	6.524572197
Species7	10	10	10
Species8	3	1.431363764	0.682934075
Species9	1	0	0
Species10	3	1.431363764	0.682934075
Species11	2	0.602059991	0.181238117
Species12	1	0	0
Species13	3	1.431363764	0.682934075
Species14	1	0	0
Species15	1	0	0
Species16	5	3.494850022	2.442795335
Species17	1	0	0
Species18	2	0.602059991	0.181238117
Species19	8	7.224719896	6.524572197
Species20	1	0	0
Total	66	43.38237608	35.35068873
Variance			**0.001569117**
	CMC 200 m		
Species1	2	0.602059991	0.181238117
Species2	1	0	0
Species3	1	0	0
Species4	8	7.224719896	6.524572197
Species5	25	34.94850022	48.8559067
Species6	1	0	0
Species7	1	0	0
Species8	2	0.602059991	0.181238117
Species9	1	0	0
Species10	7	5.91568628	4.999334881
Species11	7	5.91568628	4.999334881
Species12	2	0.602059991	0.181238117
Species13	1	0	0
Species14	9	8.588182585	8.195208901

Species15	5	3.494850022	2.442795335
Species16	2	0.602059991	0.181238117
Species17	1	0	0
Species18	1	0	0
Species19	2	0.602059991	0.181238117
Total	79	69.09792524	76.92334347
Variance			**0.002641618**
Std. Dev (H1-H2)			**0.06489018**

Diversity Index 1	**3.398**
Diversity Index 2	**3.861**

t-calculated			**-7.135131991**
V-calculated	1.77303E-05	1.25636E-07	**141.1243516**

Observed p-value	**p =**	**0.000** (1-tailed test)	**0.000** (2-tailed test)

Conclusion:

The p-value of **0.000** **Is** < **0.05**

Therefore the value of |t| **Is** **far from 0.**

Therefore there **is a** **significant difference between H'1 and H'2.**

Appendix 13. Calculation of Zar's Modified t-test for DFM 500 m data and CMC 500 m data

	DFM 500m	=B1*LOG(B1)	=B1*(LOG(B1)*LOG(B1))
Species1	2	0.602059991	0.181238117
Species2	1	0	0
Species3	6	4.668907502	3.633116211
Species4	6	4.668907502	3.633116211
Species5	1	0	0
Species6	8	7.224719896	6.524572197
Species7	10	10	10
Species8	3	1.431363764	0.682934075
Species9	1	0	0
Species10	3	1.431363764	0.682934075
Species11	2	0.602059991	0.181238117
Species12	1	0	0
Species13	3	1.431363764	0.682934075
Species14	1	0	0
Species15	1	0	0
Species16	5	3.494850022	2.442795335
Species17	1	0	0
Species18	2	0.602059991	0.181238117
Species19	8	7.224719896	6.524572197
Species20	1	0	0
Total	66	43.38237608	35.35068873
Variance			**0.001569117**
	CMC 500 m		
Species1	2	0.602059991	0.181238117
Species2	5	3.494850022	2.442795335
Species3	1	0	0
Species4	1	0	0
Species5	17	20.91763166	25.73807732
Species6	3	1.431363764	0.682934075
Species7	4	2.408239965	1.449904933
Species8	6	4.668907502	3.633116211
Species9	7	5.91568628	4.999334881
Species10	3	1.431363764	0.682934075
Species11	1	0	0
Species12	4	2.408239965	1.449904933
Species13	1	0	0
Species14	4	2.408239965	1.449904933

Species15	6	4.668907502	3.633116211
Species16	3	1.431363764	0.682934075
Species17	3	1.431363764	0.682934075
Species18	4	2.408239965	1.449904933
Species19	1	0	0
Species20	2	0.602059991	0.181238117
Species21	3	1.431363764	0.682934075
Species22	3	1.431363764	0.682934075
Total	84	59.0912454	50.70614037
Variance			**0.001294981**
Std. Dev (H1-H2)			**0.053517271**

Diversity Index 1	**3.398**	
Diversity Index 2	**4.055**	

t-calculated			**-12.27641074**
V-calculated	8.20306E-06	5.7269E-08	**143.2373841**

Observed p-value	**p =**	**0.000** (1-tailed test)	**0.000** (2-tailed test)	
Conclusion:				
The p-value of	**0.000**	**Is**	<	**0.05**
Therefore the value of |t|		**Is**	**far from 0.**	
Therefore	**there**	**is a**	**significant difference between H'1 and H'2.**	

Appendix 14. Calculation of Zar's Modified t-test for CMC 200 m data and CMC 500 m data

	CMC 200m	=B1*LOG(B1)	=B1*(LOG(B1)*LOG(B1))
Species1	2	0.602059991	0.181238117
Species2	1	0	0
Species3	1	0	0
Species4	8	7.224719896	6.524572197
Species5	25	34.94850022	48.8559067
Species6	1	0	0
Species7	1	0	0
Species8	2	0.602059991	0.181238117
Species9	1	0	0
Species10	7	5.91568628	4.999334881
Species11	7	5.91568628	4.999334881
Species12	2	0.602059991	0.181238117
Species13	1	0	0
Species14	9	8.588182585	8.195208901
Species15	5	3.494850022	2.442795335
Species16	2	0.602059991	0.181238117
Species17	1	0	0
Species18	1	0	0
Species19	2	0.602059991	0.181238117
Total	79	69.09792524	76.92334347
Variance			**0.002641618**
	CMC 500 m		
Species1	2	0.602059991	0.181238117
Species2	5	3.494850022	2.442795335
Species3	1	0	0
Species4	1	0	0
Species5	17	20.91763166	25.73807732
Species6	3	1.431363764	0.682934075
Species7	4	2.408239965	1.449904933
Species8	6	4.668907502	3.633116211
Species9	7	5.91568628	4.999334881
Species10	3	1.431363764	0.682934075
Species11	1	0	0
Species12	4	2.408239965	1.449904933
Species13	1	0	0
Species14	4	2.408239965	1.449904933
Species15	6	4.668907502	3.633116211

Species16	3	1.431363764	0.682934075
Species17	3	1.431363764	0.682934075
Species18	4	2.408239965	1.449904933
Species19	1	0	0
Species20	2	0.602059991	0.181238117
Species21	3	1.431363764	0.682934075
Species22	3	1.431363764	0.682934075
Total	84	59.0912454	50.70614037
Variance			**0.001294981**
Std. Dev (H1-H2)			**0.062742326**

Diversity Index 1	**3.861**
Diversity Index 2	**4.055**

t-calculated			**-3.092011597**
V-calculated	1.54968E-05	1.08295E-07	**143.098186**

Observed p-value	**p =**	**0.002** (1-tailed test)	**0.001** (2-tailed test)

Conclusion:

The p-value of	**0.002**	**Is**	<	**0.05**

Therefore the value of |t| <u>Is</u> far from 0.

Therefore there <u>is a</u> significant difference between H'1 and H'2.

Appendix 15. Total number of species and individuals of birds entering the boundary net according to different time period, Betong, Sarawak.

Family	Common Name	Species Name	Morning (6am-9.59am)		Middle of the day (10am-3.59pm)		Late afternoon (4pm-6pm)		**Total**
			OP→F	F→OP	OP→F	F→OP	OP→F	F→OP	
Timaliidae	Chestnut-rumped Babbler	*Stachyris maculate*	2	1					**3**
	Bold- striped Tit Babbler	*Macronous bornensis*	9	3	1		3		**16**
	Scaly-crowned babbler	*Malacopteron cinereum*	1						**1**
Nectarinidae	Brown-throated sunbird	*Anthreptes malacensis*			1		1		**2**
	Ruby-cheeked sunbird	*Anthreptes singalensis*					1		**1**
	Little spiderhunter	*Arachnothera longirostra*	1						**1**
Pycnonotidae	Yellow-vented bulbul	*Pycnonotus goiavier*	3	1	1		1	2	**8**
	Olive winged bubul	*Pycnonotus plumosus*	2	2		1			**5**
	Hairy-backed bulbul	*Tricholestes criniger*					1		**1**
	Hook-billed bulbul	*Setornis criniger*						1	**1**
Cisticolidae	Rufous-tailed tailorbird	*Orthotomus sericeus*	2	1					**3**
	Ashy Tailorbird	*Orthotomus ruficeps*						2	**2**
	Yellow-bellied prinia	*Prinia flaviventris*	2	1	1			1	**5**
Strigidae	Reddish Scope owl	*Otus rufescens*						1	**1**
Estrildidae	Dusky munia	*Lonchura fuscans*		1			1	1	**3**

Cuculidae	Plaintive cuckoo	*Cacomantis merulinus*	1	2	1					**4**
Caprimulgidae	Large-tailed Nightjar	*Caprimulgus macrurus*	3							**3**
Apodidae	Sliver rumped Spinetail	*Rhaphidura leucopygialis*		2			1	1		**4**
Tytonidae	Orential Bay Owl	*Phodilus badius*	1							**1**
Hirundinidae	Pacific Swallow	*Hirundo tahitica*	6		4	1	2			**13**
Muscicapidae	Oriental magpie robin	*Copsychus saularis*	1			1				**2**
	Grey-chested Jungle-flycatcher	*Rhinomyias umbratilia*	1							**1**
Rhipiduridae	Pied fantail	*Rhipidura javanica*		2		1				**3**
Alcedinidae	Stork-billed kingfisher	*Pelargopsis capensis*	1	2	1		1			**5**
Picidae	Rufous Piculet	*Sasia abnormis*		1			1			**2**
Pittidae	Blue-winged Pitta	*Pitta moluccensis*					1			**1**
Sylviidae	Oriental reed warbler	*Acrocephalus orientalis*	1							**1**
Ramphastidae	Red-crowned Barbet	*Megalaima rafflesii*			1					**1**

Appendix 16. Chi-square test for direction of birds entry into boundary net

	Direction of entry into net			
Time	From Plantation	From Forest	Total	
Total	60	32	92	
O	**E**	**O-E**	**(O-E)*2**	**(O-E)*2/E**
60	46	14	196	4.26087
32	46	-14	196	4.26087
			Total	8.521739

Critical value from Chi-squared Distribution Table, Critical value = 6.68

df= (2-1=1), 0.05

The critical value from Chi-squared Distribution Table (degree of freedom = 1) is 6.68, so the calculated Chi- squared value of $\chi 2$ that we obtained (8.52) is significant at the 5% level. Hence, there is significant difference on the direction of birds entering the boundary net from plantation and from the adjacent forest.

Appendix 17. Chi-square test for frequency of birds entry into boundary net at different time

Frequency of bird hit the net at different time				
Time	Total			
6am-9.59am	54			
10 am – 3.59 pm	15			
4.00 pm-6.00 pm	23			
Total	92			
O	**E**	**O-E**	**(O-E)*2**	**(O-E)*2/E**
54	30.67	23.33	544.2889	17.74662211
15	30.67	-15.67	245.5489	8.006159113
23	30.67	-7.67	58.8289	1.918125204
			Total	27.67090642

Critical value from Chi-squared Distribution Table, Critical value = 5.99

df= (3-1=2), 0.05

The critical value from Chi-squared Distribution Table (degree of freedom = 2) is 5.99, so the value of $\chi 2$ showed that (27.67) is significant at the 5% level. Hence, conclude that there is significant difference on the frequency of bird hitting the boundary net at different time.

Appendix 18. Plants and insects found in the stomach contents of Yellow-vented samples

	Yellow-vented Bulbul	Plant	Annelids	Diptera	Hemiptera	Hymenoptera	Homoptera	Coleoptera				
Month-Year	Samples	Parts	Hap	Cul	Unid	Form	Cica	Staphy	Scoly	Curc	Unid	Notes
Mar-11	B07862		√	√								
	B07871			√	√							
	DFM031101			√								
	DFM031102											EMPTY
	DFM031103		√									
	DFM031104		√					√	√			
	DFM031105		√									
	DFM031106											EMPTY
	DFM031107											EMPTY
May-11	DFM051108	√	√									
	DFM051109											EMPTY
	DFM051110									√		
	DFM051111									√		
	DFM051112											EMPTY
	DFM051113											EMPTY
	DFM051114									√		

	DFM051115					√	
Jul-11	DFM071116		√				
	DFM071117				√		
	DFM071118	√					
Nov-11	DFM111119	√					
Jan-12	DFM011220					√	
	DFM011221						EMPTY
May-12	DFM051222	√				√	
	DFM051223					√	
	DFM051224					√	
	DFM051225						EMPTY
	DFM051226						EMPTY
	DFM051227						EMPTY
	DFM051228						EMPTY
Jul-12	DFM071229	√					
	DFM071230						EMPTY
Nov-12				**No Yellow-vented Bulbul caught at this month**			
Feb-13	DFM021331	√				√	
	DFM021332						
	DFM021333	√					

	DFM021334	√						
	DFM021335	√						
	DFM021336	√						
	DFM021337	√						
	DFM021338							EMPTY
May-13	DFM051339	√						
	DFM051340	√				√	√	
	DFM051341			√		√		
	B08656					√		

Hap : Haplotaxida Culi : Culicidae Staphy : Staphylinidae

Form : Formicidae Cica : Cicadellidae Scoly : Scolytidae

Curc : Curculionidae Unid : Unidentify

Appendix 19: Insect appendages parts found in stomach content of Yellow-vented Bulbul

Insect parts:
-Second wing
-Order Hemiptera

Insect parts:
-Order Diptera
-Family Culicidae

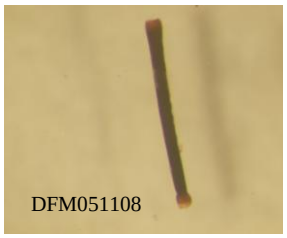
Insect parts:
-Order Diptera
-Family Culicidae

Insect parts:
-Order Diptera
-Family Culicidae

Insect parts:
-Leg parts
-Unknown order

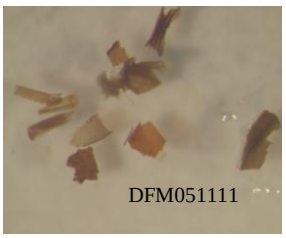
Insect parts:
-Order Coleoptera
- Family Staphylinidae

Insect parts:
-Order Coleoptera
- Family Scolytidae



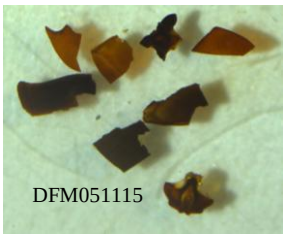
Insect parts:
-Leg part
-Unknown order

Insect parts:
-Class Annelids



Insect parts:
-Head part
-Unknown order

Insect parts:
-Head and leg part
-Order Coleoptera



Insect parts:
-Head and abdomen part
-Order Coleoptera

Insect parts:
-Class Annelids

Insect parts:
-Order Hymenoptera
-Family Formicidae

Insect parts:
- Mandible, wing and abdomen part
- Order Coleoptera
- Family Curculidae

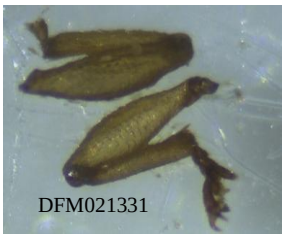
Insect parts:
- Leg part
- Order Coleoptera
- Family Curculidae

Insect parts:
- Head and abdomen part
- Order Coleoptera
- Family Curculidae

Insect parts:
- Snout part
- Order Coleoptera
- Family Curculidae

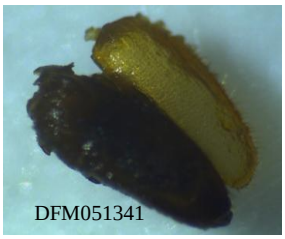
Insect parts:
- Leg part
- Order Coleoptera
- Family Curculidae

Insect parts:
- Wing part
- Order Coleoptera
- Family Curculidae

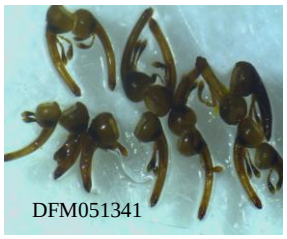


Insect parts:
- Leg part
- Order Coleoptera
- Family Curculidae

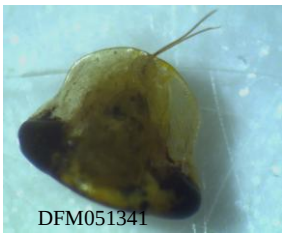
Insect parts:
- Leg part
- Unknown order



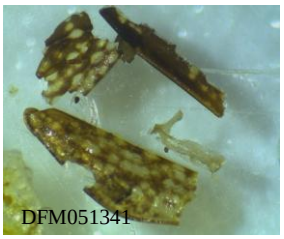
Insect parts:
- Body part
- Order Coleoptera
- Family Curculidae



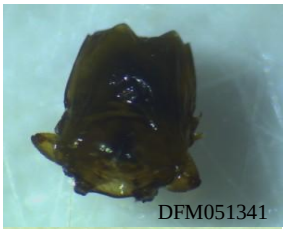
Insect parts:
- Snout part
- Order Coleoptera
- Family Curculidae



Insect parts:
- Head part
- Order Homoptera



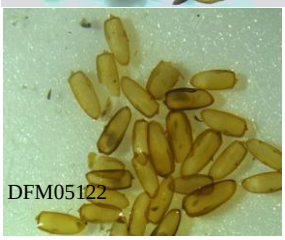
Insect parts:
-Wing part
-Unknown order



Insect parts:
- Body part
- Order Homoptera

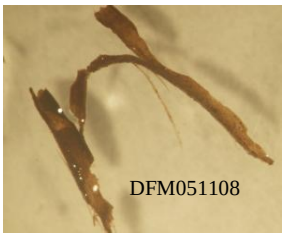
Insect parts:
- Leg and Head part
- Order Coleoptera
- Family Curculidae

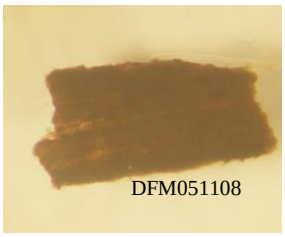
Insect parts:
-Snout part
-Order Coleoptera
-Family Curculionidae

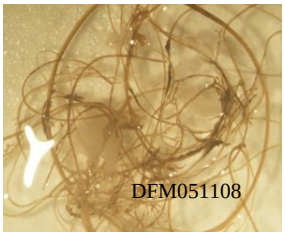


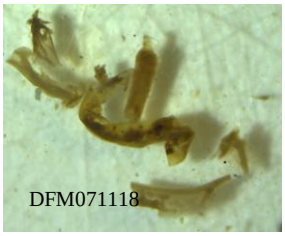
Insect parts:
-Elytra part
-Order Coleoptera
-Family Curculionidae

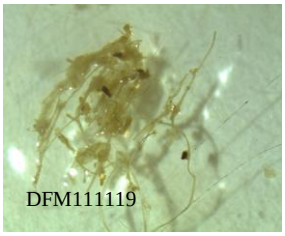
Appendix 20. Plant part found in the stomach of Yellow-vented Bulbul

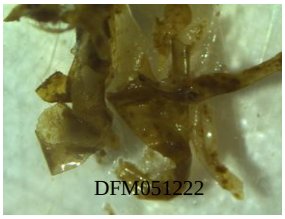


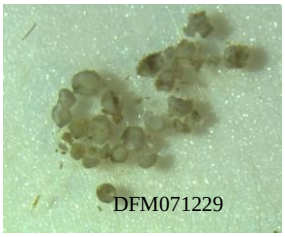












Appendix 21: The list of recaptured birds according to time of captured, where they captured and at which sampling time.

		Time of Captured				
		1st	**2nd**	**3rd**	**4th**	**5th**
Species Name	Ring No	(Site/Sampling time)	(Site/Sampling time)	(Site/Sampling time)	(Site/Sampling time)	(Site/Sampling time)
Yellow-vented Bulbul	B07865	OP/1st	OP/1st	OP/3rd		
Large-tailed Nightjar	C04090	OP/1st	B/2nd			
Plaintive Cuckoo	B07711	OP/1st	OP/3rd			
Plaintive Cuckoo	B07879	B/1st	OP/2nd			
Brown-throated Sunbird	A09586	B/1st	OP/3rd	OP/7th		
Bold-striped Tit-babbler	A07643	OP/3rd	OP/3rd	B/6th		
Plaintive Cuckoo	B08025	OP/3rd	B/4th	OP/7th		
Grey-chested jungle flycacther	A08446	OP/6th	CC/6th	CC/7th		
Stork-billed Kingfisher	E01034	OP/6th	CC/7th			
Magpie robin	B08497	OP/6th	OP/6th	B/6th		
Chesnut-winged babbler	A08135	CC/6th	CC/7th			
Strip tit-babbler	A08458	OP/6th	OP/7th			
Rufous piculet	A07327	CC/1st	CC/2nd			
Rufous-backed Kingfisher	A07648	CC/3rd	CC/4th	CC/4th	CC/6th	CC/6th
Rufous Piculet	A07646	OP/3rd	CC/4th			
Hook-billed bulbul	B07876	CC/6th	B/6th			
Chesnut-winged babbler	A08134	CC/6th	CC/6th			

Ruby-cheeked sunbird	A08445	CC/6th	CC/6th	CC/10th		
Buff-necked woodpecker	B08488	CC/6th	B/7th			
Black-throated babbler	B08181	CC/6th	B/7th			
Purple-naped Sunbird	A08488	OP/6th	CC/7th			
Rufous Piculet	A07644	OP/3rd	B/5th			
Bold Strip tit-babbler	A08440	B/6th	B/7th			
Pacific swallow	A08454	B/6th	B/6th			
Fluffy-backed tit-babbler	B08496	CC/6th	CC/10th			
Yellow-vented Bulbul	B08918	OP/9th	B/9th			
Total		**26**	**26**	**8**	**1**	**1**