



Institute of Biodiversity and Environmental Conservation

**Effect of Longhouse Communities on Species Diversity and Diet of
Bulbul (Aves: Pycnonotidae) in Pelagus, Kapit, Sarawak**

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**Master of Science
2020**

Effect of Longhouse Communities on Species Diversity and Diet of Bulbul
(Aves: Pycnonotidae) in Pelagus, Kapit, Sarawak

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A thesis submitted

In fulfillment of the requirements for the degree of Master of Science

(Bird Ecology)

Institute of Biodiversity and Environmental Conservation

UNIVERSITI MALAYSIA SARAWAK

2020

DECLARATION

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

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ACKNOWLEDGEMENT

My special acknowledgement goes toward my supervisor and my co-supervisor, Prof. Dr. Andrew Alek Tuen and Prof. Dr. Gabriel Tonga Noweg for advice, support, strength and precious guidance throughout this research. I am thankful for all advice and guidance from all Institute of Biodiversity and Environmental Conservation (IBEC) lecturer and staff. A wholehearted appreciation goes to my fieldwork team Hasri Al-Hafiz bin Haba, Rahah Mohd binti Yakup, Isa Sait, Adi Shabrani bin Mohammad Ridzuan, Pui Yong Min, Pang Sing Tyan, Mohd Paisal bin Wahab, Attiqah Fadziliah binti Sopian and Melynda Cheok Ka Yi. I am grateful for the help, field assistantship and accommodation provided from local community namely John anak Asun (Headman of Rumah John), Ugak anak Ribat, Jawek anak Gagat, Nicholas Bantin anak John, Bonnyson anak Gon, Alistar Keyang anak John, Temenggong anak Kumap, Bujah anak Ijau (Headman of Rumah Bujah), Win anak Meluda, Umpik anak Bunsu, Richelles Seli anak Lasu and Laja anak Sandak (Headman of Rumah Laja). I also want to express my gratitude toward Sally Soo and Stephanie Judi for helping me.

I want to express my appreciation towards Sarawak Energy Berhad, through its Hydropower Environmental Sustainability Project research grant for financial support of my fieldwork; toward Ministry of Higher Education, Malaysia for My Brain 15 scholarships and Sarawak Forestry Department for research permit (NCCD.907.4.4(JLD.12)-109) and park permit (238/2015).

My innermost gratitude is for my mother, Rohana Binti Abdullah and my late father, Ismail bin Brahim and the rest of my family and friends for giving me strength, supported me, motivate and pray for me in completing this thesis. I am so grateful for all the support and

so thankful for even the smallest help. All of our hard work and experiences will always be remembered. Thank you all and really appreciate it.

ABSTRACT

Longhouse communities can be a significant source of disturbance to local fauna by their presence in the vicinity and through their activities such as farming, hunting and gathering of forest produce. The level of disturbance is likely to be highest at sites that are closest to the longhouse and lesser at sites further away from the longhouse. Whether different levels of anthropogenic disturbance affect avifauna community have not been studied in isolated longhouse communities in Sarawak. Hence a study was conducted in the forests behind three longhouses (Rumah Laja, Rumah Bujah and Rumah John) and in Pelagus National Park (PNP) to determine the effect of anthropogenic disturbance on the diversity and diet of bulbul. Sampling stations were located at 100 m, 500 m and 1000 m away from the longhouse, and inside PNP at location which is more than 1000 m from the longhouse and protected against anthropogenic disturbance by law. Eight sets of double-stacked mist nets were deployed at each station and checked every two hours from 8am to 6.30pm for four days. Insect and fruit traps were also set at the same station to sample the potential diet of bulbuls. These locations were sampled four times over a period of 12 months between December 2014 and November 2015. Captured bulbuls were identified, ringed, measured, and administered with emetic solution to obtain regurgitation samples for dietary studies and then released back to the forest. A total of 240 individuals comprising 12 species of bulbul was captured in this study. The dominant species caught was Spectacled bulbul (*Pycnonotus erythrophthalmos*) with 19% relative abundance and followed by Puff-backed bulbul (*Pycnonotus eutilotus*) with 16% relative abundance. Based on high diversity (Simpson index = 0.862; Shannon index = 2.145) and abundance (91 individuals), the site 500 m from the longhouse is the most preferred by bulbul and this site have a high similarity to 1000 m station and Pelagus National Park site based on Morista-horn index. A total of 24 families

of plant and 494 fruit sample weighing 1.4963 kg was collected from all stations. Distance from longhouses does not seem to affect yield of fruits collected but fruit yield was highest in March/April 2015. The total number of invertebrates collected was 20,037 individuals comprising four classes of potential preys, which are arachnida, chilopoda, gastropoda and insecta. Ivlev's electivity index (E) was used to measure a degree of selection of prey by the predator. Orthoptera with E value of +0.90 and hemiptera with E value of +0.80 are the main prey selected by bulbul. Bulbuls also selected other insect orders which are coleoptera (E = +0.60), dictyoptera (E = +0.68) and isoptera (E = +0.68). The diet of bulbuls has a positive relationship with fruit weight and invertebrates in environment based on linear regression. Different habitat also offered different types of food based on food resources collection conducted in this study. This study concluded that longhouse community have a significant effect on bulbul diversity, species evenness, number of species and abundance up to 100 m from longhouses. This supported the hypothesis of this study that the impact of anthropogenic disturbances is greatest in areas closest to human settlement and less in areas that are further away.

Keyword: Bulbul, diversity, diet, Iban longhouse, anthropogenic activity

Kesan Komuniti Rumah Panjang Terhadap Kepelbagaian Spesies dan Diet Bulbul

(Aves: Aves: Pycnonotidae) in Pelagus, Kapit, Sarawak

ABSTRAK

*Komuniti rumah panjang boleh menjadi punca utama gangguan terhadap fauna tempatan dengan kehadiran mereka di kawasan sekitar dan melalui aktiviti mereka seperti berkebun, memburu dan mengumpul hasil hutan. Tahap gangguan berkemungkinan tinggi di kawasan yang dekat dengan rumah panjang dan rendah di kawasan yang jauh dari ruman panjang. Perbezaan tahap gangguan antropogenik yang menjejaskan komuniti avifauna belum lagi dipelajari di komuniti rumah panjang terpencil di Sarawak. Oleh itu satu kajian dijalankan di hutan di belakang tiga rumah panjang (Rumah Laja, Rumah Bujah dan Rumah John) dan di Taman Negara Pelagus (PNP) untuk menentukan kesan gangguan antropogenik terhadap kepelbagaian dan diet bulbul. Stesen pensampelan terletak di 100 m, 500 m dan 1000 m dari rumah panjang, dan di dalam PNP di lokasi yang lebih daripada 1000 m dari rumah panjang dan dilindungi terhadap gangguan antropogenik oleh undang-undang. Lapan set jaring kabut berganda dilancarkan di setiap stesen dan diperiksa setiap dua jam dari pukul 8 pagi hingga 6.30 petang selama empat hari. Serangga dan perangkap buah juga ditetapkan di stesen yang sama untuk mengambil sampel makanan potensi bulbul. Lokasi-lokasi ini telah dilawat sebanyak empat kali dalam tempoh 12 bulan antara Disember 2014 dan November 2015. Bulbul yang ditangkap telah dikenalpasti, dicincin, diukur, dan diberikan cecair emetik untuk mendapatkan sampel regurgitasi untuk kajian diet dan kemudian dibebaskan kembali ke hutan. Sebanyak 240 individu terdiri daripada 12 jenis bulbul yang ditangkap dalam kajian ini. Spesies dominan yang ditangkap adalah Merbah mata merah kecil (*Pycnonotus erythrophthalmos*) dengan 19% kelimpahan relatif dan diikuti oleh Merbah coklat berjambul (*Pycnonotus eutilotus*) dengan kelimpahan relatif*

sebanyak 16%. Berdasarkan kepelbagaian yang tinggi (Indeks Simpson = 0.862; Shannon index = 2.145) dan kelimpahan (91 individu), stesen 500 m dari rumah panjang adalah stesen yang paling disukai oleh bulbul dan stesen ini mempunyai persamaan yang tinggi dengan stesen 1000 m dan Taman Negara Pelagus berdasarkan indeks Morista-horn. Sejumlah 24 keluarga tumbuhan dan 494 sampel buah seberat 1.4963 kg telah dikumpulkan dari semua stesen. Jarak dari rumah panjang seolah-olah tidak menjejaskan hasil buah-buahan yang dikumpulkan dan hasil buah yang tertinggi adalah pada bulan Mac/April 2015. Jumlah bilangan invertebrata yang dikumpulkan adalah 20,037 individu yang terdiri daripada empat kelas potensi mangsa, iaitu arachnida, chilopoda, gastropoda dan serangga. Indeks elektiviti Ivlev (E) digunakan untuk mengukur tahap pemilihan mangsa oleh pemangsa. Orthoptera dengan nilai $E +0.90$ dan hemiptera dengan nilai $E +0.80$ adalah mangsa utama yang dipilih oleh bulbul. Bulbul juga memilih serangga lain iaitu coleoptera ($E = + 0.60$), dictyoptera ($E = + 0.68$) dan isoptera ($E = + 0.68$). Pemakanan bulbul mempunyai hubungan positif dengan berat buah dan invertebrata dalam persekitaran berdasarkan regresi linear. Habitat yang berbeza juga menawarkan pelbagai jenis makanan berasaskan pengumpulan sumber makanan yang dijalankan dalam kajian ini. Kajian ini menyimpulkan bahawa komuniti rumah panjang mempunyai kesan yang signifikan terhadap kepelbagaian bulbul, kesamaan spesies, bilangan spesis dan kelimpahan sehingga 100 m dari rumah panjang. Ini menyokong hipotesis kajian ini bahawa kesan gangguan antropogenik adalah paling besar di kawasan-kawasan yang paling dekat dengan penempatan manusia dan kurang di kawasan-kawasan yang lebih jauh.

Kata kunci: Bulbul, kepelbagaian, diet, rumah panjang Iban, aktiviti antropogenik

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LIST OF ABBREVIATIONS

asl	Above sea level
Cm	Centimeter
FAO	Food and Agricultural Organization of the United Nations
g	Gram
ha	Hectare
IBEC	Institute of Biodiversity and Environmental Conservation
km	Kilometer
m	Meter
mm	Millimeter
ml	Milliliter
PNP	Pelagus National Park
UNIMAS	Universiti Malaysia Sarawak

CHAPTER 1

INTRODUCTION

1.1 Indigenous Communities

Longhouses or rumah panjang is a type of traditional settlement for natives in Borneo Island (Cramb, 2007). Traditionally longhouse is an elevated wooden structure that is built near a river, which provided access to other areas and water for bathing, washing and drinking. Longhouses communities conducted many activities such as farming, fishing and collecting forest produce to support their livelihood. Shifting cultivation is the most common farming practices of the Iban longhouse communities (Cramb, 1993) and it is one of primary causes of degradation and loss of tropical rainforest in South East Asian because each year new areas are opened up for cultivation (Ichikawa, 2007). As a consequence, farms get further and further away from the original longhouse and eventually a new longhouse is built in the newly farmed area (Yea, 2002).

In the last 40 years however the Iban and other minority groups in Sarawak are encouraged by the government to adopted more sedentary lifestyle by building a permanent structure such as using concrete, corrugated iron and glass (Yea, 2002). Recently, tourism has become an alternative source of livelihood as shown by Longhouse tour and “River Safari” in area Batang Ai, Lemanak, Engkari and Ulu Ai river in Sri Aman division (Yea, 2002) and in Kelabit Highlands (Hitchner et al., 2009). Longhouse communities, especially the women, elderly and landless, can also generate income through production and sales of handicraft such as basket, mat plaiting, weaving pua (ceremonial blanket), weaving Kelambis (Jacket), making selampai (sashes), carving terabai (shields), kenyalang image and sungkup (funerary monument) (Berma, 2001).

This study focuses on the Iban community in Pelagus, located in central Sarawak, along the Rajang River. The Iban is the largest of indigenous people in Sarawak, numbering about about 797,700 in 2016 (The Official Portal of Sarawak Data, 2018). They practiced shifting cultivation to plant paddy, and after harvesting the paddy they plant rubber and fruit trees on the fallow land thus creating an agroforestry system. They also hunt, collect forest produce from the communal forest surrounding their longhouse and fish in the major rivers (Rajang River, Pelagus River) which is also their main means of transport. The mechanism to create communal forest was by having an agreement or mutual understanding with logging companies, which limit logging activities to areas outside 1000 m radius from their longhouses.

Globally, indigenous people-inhabited areas occur simultaneously with world remaining major concentration of biodiversity, with an estimated 22% of the world land surface under traditional indigenous communities holding 80% of the planet's biodiversity (WRI, 2005). About 11% of the world forest land are legally owned by indigenous people and communities (White et al., 2004; Takeuchi et al., 2017). It is suggested that when indigenous communities are small in numbers, adhere to traditional systems and methods of resource exploitation and harvest only for self-consumption, their impact on ecosystem function and biodiversity is minimal. According to Persha et al. (2011), forest systems are more likely to have sustainable outcome (above average tree species richness and subsistence livelihoods) when local forest users participate in the forest rulemaking. A study by Takeuchi et al. (2017) showed that the tree diversity in communal reserve forest belonging to Iban and Penan community in Sarawak, Borneo, is similar to that of primary forest.

Globalization factors such as market assess, migration and technology network have implication toward household economics, social network and native biodiversity (Kramer et

al., 2009). This implication can be illustrated by the rising prices for local products that resulted in intensification of production or increases their land holding through deforestation that associated with habitat loss, nutrient runoff, pollution and species decline (Geist & Lambin, 2002). They may also shift from traditional produce crops to one better-suited for export (rubber, oil palm) that often comes with harmful ecological consequences (Amadi, 1988).

1.2 Disturbed Forest and Its Avifauna Community

The tropical forest is an important habitat due to its high diversity, ancient and unique ecology of land communities (Myers, 1984). Tropical forest is being threatened by deforestation and degradation caused mostly by settlement, logging and agricultural activities. Based on satellite imagery, it is estimated that by 2009 over 80% of Sarawak and Sabah forest is degraded (Bryan et al., 2013). Oil palm plantation in Sarawak has increased in size from 28,500 ha in 1985 to 744 372 ha in 2008 (Tsuyuki et al., 2011) and increases even more in the year 2018 with 1,572,477 ha (MPOB, 2019). Based on Global Witness (2012), only 5% of Sarawak forests remain in pristine state and degradation of virgin forest in Sarawak is surprisingly more than Sabah, Indonesia and Brunei combined. Increases proportion of disturbed forest has make it important to study the biodiversity of these areas and try to understand some of the factors that maintain diversity.

Disturbance towards the environment has a potentially damaging effect on wildlife (Hume, 1976). Disturbance is often label as event such as hurricane, forest fires or anthropogenic activities such as logging, land clearing and infrastructure development (McKelvey, 2015). Avian community has been affected widely by habitat modification caused by agriculture, settlement and logging activities. Oil palm plantation only retains about 20% of previous forest inhabitants of mammal, reptiles and birds (Laidlaw, 1998; Heang & Lim, 1998).

According to Gibson et al. (2011), bird is most sensitive to forest conversion into agriculture. In Ulu-Segama-Malua forest reserve in Sabah, the abundance of imperiled bird species in forest fragment is 60 times lower and in oil palm plantation 200 times lower than in contiguous forest (Edwards et al., 2010).

Forest disturbance has an impact on decreasing food supply that can affect bird diversity, abundance, breeding ecology, body condition, ranging and/or flocking behaviour (Sodhi, 2002). Wong (1986) studied the effect of food supply of understory bird in primary and disturbed forest in Pasoh Forest Reserve, Negeri Sembilan, Malaysia. Plant producing flowers or fruits used by birds in primary forest is higher than in disturbed forest; foliage arthropods abundance did not differ between two forest but low abundance period is four months longer in disturbed than in primary forest. Bird species richness and abundance were lower in disturbed than primary forest, and this is due to lower abundance of resource in disturbed forest than primary forest (Wong, 1986). Aratrakorn et al. (2006), compared the oil palm and rubber plantation versus lowland forest in Khao Pra-Bang Khram Wildlife Sanctuary and Bang Khram National Reserve Forest in Thailand and showed that species richness is lower in the plantation compared to lowland forest. Barbet, woodpecker and babbler are largely absent in the plantation and 15 out 16 globally threatened or near threatened species can be found only in lowland forest (Aratrakorn et al., 2006). The impact of habitat fragmentation on tropical bird community was also studied in Lake Kenyir, Malaysia by Ding et al. (2011). Based on the study, smaller islands have simpler bird communities and contains less functional group at feeding guilds level. Insectivorous and frugivorous birds are the most affected by forest fragmentation (Sodhi et al., 2004).

Bulbul (Family Pycnonotidae) comprised of 161 species worldwide (IUCN, 2019), 68 species in Southeast Asian (Avibase, 2019) and 27 species in Borneo (Avibase, 2019). Based

on Phillipps and Phillipps (2014), the Bornean Bulbul is endemic to Borneo Island. This species occurs in the south to Barito Ulu, Kalimantan and is locally common in some places such as Crocker Range, and scarce on Mount Kinabalu but not found on Gunung Penrissen and Gunung Pueh, Sarawak. Bulbuls do not migrate, and sexes are alike (Smythies, 1981).

Bulbul is a generalist frugivore that feeds on a broad type of fruits (Fukui, 1995; Corlett, 1998a). Frugivorous bird has dominant roles in mutualism as seed dispersal, which can be understood using diet studies (Corlett, 1998a; Wenny, 2000; Corlett, 2009). Bulbuls preferably feed on fruit and berries (Fogden, 1972) but flowers, buds and insects are also consumed when fruits and berries are scarce (Brooks, 2013). Black-crested Bulbul takes insect on wing regularly and Yellow-vented Bulbul regularly feeds from the ground on prey that included worms, scarabs, and crickets (Smythies, 1981). A study in Semengo Forest Reserve, Sarawak showed that fruit may be essential for a bulbul diet where they consumed them even when the insect is abundant (Fogden, 1972). More than 90% of bulbul dropping has plant material in them (Mandon-Dalger et al., 2004; Milla et al., 2005; Linnebjerg, 2010) and the rest are insects.

1.3 Problem Statement, Research Questions and Hypothesis

Globally, indigenous people-inhabited or controlled areas coincided with the world's remaining centres of biodiversity (WRI, 2005; Sobrevila, 2008). It is suggested that when indigenous communities are small in numbers, adhere to traditional culture and systems of resource exploitation and harvest only for self-consumption, their impact on ecosystem function and biodiversity would be minimal, hence the high biodiversity of indigenous people occupied areas. Applying this global view to the Iban in Pelagus, their impact on avifauna diversity in the surrounding forest is going to depend on whether the three assumptions holds true or not: (i) that their population remain small and isolated (ii) they

follow traditional system of land management and resource exploitation, (iii) they harvest resources only for their own consumption. Even if the assumptions hold true, their daily activities will be greatest closer to the longhouse, simply because of the greater effort required to venture further. Furthermore, the area beyond 1000 m was under logging concession and not accessible to those not connected with logging activities.

This study focuses on distances from a longhouse (100 m, 500 m and 1000 m) from longhouse) as a factor and using bulbul as an ecological indicator to show the effect of longhouses community toward bulbul diversity and its diet. Bulbul was chosen because they can be found extensively in Borneo with over 27 species (Avibase, 2019), occupying a wide variety of habitats and therefore relatively easy to capture. Additionally, forest bulbuls are important small frugivores (Corlett, 1998a), feeding on figs and other sugar-rich fruit (Wells, 1975; Wong, 1986; Lambert, 1989) and lipid-rich capsular fruit (Pannell & Koziol, 1987).

Food resources are one of the environmental factors that maintain species diversity. This study also focuses on food resources as the parameter through which anthropogenic disturbance from longhouses community influenced diversity. This anthropogenic disturbance causes different forest structure in study area (logged forest, secondary forest and agroforest) and thus different site or distances will offer different food resources, which in turn influence the bulbul community.

The research question to be addressed in this study are:

- i. What bulbul species are found at different distance from longhouses (100 m, 500 m and 1000 m) and what to be found at totally protected area Pelagus National Park?
- ii. What are the food resources that attract bulbuls to a particular site?

- iii. What does bulbul eat? What do they prefer? Do they feed based on availability, for example when there are plenty of fruits in the forest, they will eat more fruit but when there are no fruits they will feed on insect?

The hypothesis of this study is that the impact of anthropogenic disturbances towards bird communities is greatest in areas closest to human settlement (e.g; 100 m) and least in areas that are further away where the null hypothesis shows no significant differences between two sites.

The second hypothesis of this study is that the bulbul diet. It is hypothesized that the diet of bulbul depends on available food resources, some of which will be selected based on the species' preference while others will be consumed because they are abundant.

1.4 Objectives

The objectives of this study are:

- i) To determine the species richness, abundance, evenness and species assemblage of bulbul occupying different distances (100 m, 500 m, 1000 m) from longhouses, including Pelagus National Park which is >1000 m from the longhouse.
- ii) To determine the availability of food resource (invertebrates and fruits resources) available for bulbuls and temporal abundance at different distances from the longhouse.
- iii) To determine diet of bulbul and its relationship to food availability in the environment.

CHAPTER 2

LITERATURE REVIEW

2.1 History of Anthropogenic Activities in Borneo, Sarawak and Rajang Basin

Anthropogenic is an adjective that refers to an effect on nature that are caused by human (Ansari & Matondkar, 2014). Any activities done by humans are therefore anthropogenic activities. Humans have existed in Borneo for as long as 50,000 years ago based on the excavated artifact and remains found in Niah Caves during the early of 1950's (Harrison, 1959). Evidence (ash and rice phytoliths) from Loagan Bunut sediments dated about 7000 years ago indicated early activities conducted by human in Borneo include farming (Hunt & Premathilake, 2012), suggesting that this was a long-lived and stable system of land management, which must have been at least partly for food production (Hunt & Rabett, 2014). Hunt et al. (2012) also discovered biomass burning at Great cave of Niah associated with the practice of earliest human activities. Archeological pieces of evidence such as stone flakes (Harrison, 1959), a bone tool and pig tusk ground to give sharp end, bone 'gorge' (Harrison & Medway, 1962) and animal remains (Medway, 1960a; Medway, 1960b; Hooijer, 1963; Medway, 1965) showed that hunting was an important activity through which early humans impacted the environment. This early form of hunting to meet nutritional need of a much smaller human population was sustainable.

Later as the world's economy developed and human population increased dramatically, people began to put a monetary value to resources, starting what is now known as commercial exploitation (Lewis et al., 2015). Growth of modern human has led to urbanization, natural resources exploitation, food production (agriculture), industrial production (includes pharmaceutical) (Chan, 2010). Commercial hunting has led to the

demise of many species globally (Redford, 1992). For example, Sumatran rhinoceros once roam across South East Asia, this species is now restricted to small isolated populations occurring in Burma, Thailand, Malay Peninsula, Sumatra and Borneo (Van Strien, 1974; McNeely & Laurie, 1977; Payne, 1980). Excessive hunting has a big impact on their number and distribution (Van Strien, 1974). Between the years 1970 and 1987, an estimated 85% of the world's rhino population was lost (Fitzgerald, 1989). Sumatran rhino is now considered extinct in Malaysia when the last captive animal died in November 2019 (Bittel, 2019). Modern human and their idea of urbanization of habitat has significantly impacted the environment by changing of atmospheric characteristics, hydrological characteristics, lithospheric characteristics, the biosphere, and cryosphere (Chan, 2010). These changes have resulted in climate changes, floods, droughts, water crises, loss of natural habitats and sea level rise (Chan, 2010).

Sarawak is rich in natural resources and biodiversity. This richness of resources has attracted people to invest in Sarawak and at the same time leaving an impact on the environment. Share of mining and quarrying in the state's GDP increases from 0.4% in 1967 to 18% in 1973 (Leigh, 1979). This rapid pace of economic development for the period 1962-1974 is mainly due to petroleum output accompanied by a four-fold increase in the price of petroleum (Leigh, 1979). Timber export in Sarawak during the year of 1970 was worth RM 113 million and increased to a total of RM 236 million in 1980 (Malaysian Information Services Department, 1993). Export value of timber and timber product of Sarawak exceeded RM 7.4 billion in 2012 (Lissem, 2013).

Logging in the Rajang Basin in the 1970s contributed significantly to the speedy economic development that accelerates the social change in Sarawak (Fong, 1996). The impact of logging is not only the removal of commercial timber trees but included accidental damage

to other trees, lianas and figs that take place during tree felling and road construction (John, 1988). This inevitably reduces the number of fruit-bearing trees thus lowering the carrying capacity of the habitat and wildlife density. In addition, logging roads open the interior areas to further anthropogenic disturbances such as land modification, illegal logging, agriculture and hunting. A total logging road of 364,489 km were built in Malaysia Borneo and Brunei combined in year between 1990 and 2009 (Bryan et al., 2013). Sarawak's severely degraded forest comprised of 77% of forest that has been logged twice, 19% of logged three times and 3% for four and more times (Bryan et al., 2013). An estimated 22% of land surface in Sabah and Sarawak is intact unlogged forest. The unnecessary destructive timber harvesting practices concerns has stimulated the development of reduced-impact logging (RIL) project in Sabah in 1992. This project restricted harvest planning, vine cutting, directional felling, and skidding and this contribute to a reduction in stand damage from 50% to 28% of the original stems; damage to soil was reduced from 13% to 9% of total area in RIL relative to conventional logging areas (Pinard et al., 2000). Residual stands in RIL areas had greater vertical structure and better stocking of commercial timber species than stands in conventionally logged areas and this bring a great benefit for conservation of biodiversity and sustainability of timber production (Pinard et al., 2000).

2.2 Threats to Forest

Forest need to be maintained due to its importance in providing ecosystem services to wildlife and humans. For example, over 2/3 of the world's water originates from a course through and are influenced by forest, which provided services such as water filtration and cycling, flow rates, flood control, climate regulation and soil erosion control. Forest have provided many resources for bird community such as food (fruit, insect), shelter, breeding

ground and many more. In addition, forest provides structural habitat for numerous species, provide home for wildlife.

The forest habitat for wildlife has been threatened by deforestation and degradation associated with anthropogenic activities such as agriculture and logging. Forest of the world is declining in size both international and globally. Forest destruction also can be detected even in vast rainforest and secluded place such as in Sungai Rajang and even in Pelagus.

There is approximately 30% of forest cover from the Earth's land area (Keenan et al., 2015). Based on FAO (2016), forest area of the world in the year 2015 is 3999 million ha with 3695 million ha of natural forest and 291 million ha of planted forest. In 1990 the world has 4128 million ha of forest (31.6% of global land area) and this decreased to 3999 million ha in 2015 (30.6% of global land area) (FAO, 2016). This is a change from 31.6% to 30.6% of global land area from 1990 to 2015 (FAO, 2016). In the year 2015, average annual reforestation is 27 million ha. The area for conservation of biodiversity in 2015 is 524 million ha with an annual change of 1.75% has in an increase direction of changes during this previous year. At the same time, the area of primary forest of the world has decreased its area from previous years with an annual change rate of -0.1% from 1277 million ha. In the year 1990, the world has 4128 million ha of forest meanwhile in 2015 the area has decreased to 3999 million ha. Agricultural land also continues to expand in 70% of countries (FAO, 2003). Globally, deforestation is declining annually in the 1990s from 16 million ha to 13 million ha annually between 2000 and 2010 (FAO, 2010). Rate of deforestation at 0.08% in the year of 2010 to 2015 is still a concern because of the loss occurring in areas with particularly high ecological value (Morales-Hidalgo et al., 2015). Mittermeier et al. (2004) identified 34 'biodiversity hotspots' in the world, areas containing a high concentration of endemic species and undergoing immerse habitat loss.

Southeast Asia containing the world's third largest tropical forest with 60% of tropical rainforest, 15% tropical moist deciduous forest, 15% tropical dry forest and 10% mountain forest (FAO, 2016). Southeast Asia containing 15% of the world's tropical forest (FAO 1995). Roughly the entire Southeast Asia was covered by forest 8000 years ago (Billington et al., 1996). Presently, half of the whole region's area is covered and a rapid decline in the forest area. In the year 2005, only 42.8% of the original forest remaining (FAO, 2006). The year of 1880 and 1980, Southeast Asia undergo an emerged decline of 0.3% forest loss that generally from agricultural expansion and commercial logging (Flint, 1994). According to Mittermeier et al. (2004) identified 34 'biodiversity hotspots' in the world as the areas containing a high concentration of endemic and undergoing immerse habitat loss Southeast Asia. Southeast Asia covers around 5 million km² of land area that can be divided into two distinctively different regions, which is continental Southeast Asia 2.2 million km² and insular Southeast Asia 2.7 million km² (Stibig et al., 2014). Between 1880 and 1980, Southeast Asia forest cover decreased by 29% and cultivated land expanded by 86% (Flint, 1994). Presently only half of the region's area is covered by forest and this is declining rapidly, with only 42.8% of the original forest remaining in 2005 (FAO, 2006). Noticeable changes in a total forested area in Southeast Asia were observed from the year 1990 to 2010, with 268.0 million ha declining to 236.3 million ha, respectively (Stibig et al., 2014). Tropical forest in Southeast Asia's functioning as environment protection and a biodiversity hotspot in addition to its role in socio-economic development and the living condition livelihood of the forest-dependent population (Lee, 2009; Stibig et al., 2014). Noticeable changes in a total forested area in Southeast Asia are observed from the year 1990 to 2010 with 268.0 million ha and 236.3 million ha respectively (Stibig et al., 2014).

Malaysia's forests are complex ecosystems and rich in biodiversity. Estimated over 15,000 species of vascular plants, 306 species wild mammals, more than 742 species of birds, 567 species of reptiles, 242 species of amphibians, about 1,619 species of marine fish, more than 449 species of freshwater fish, 612 species of coral and over 150,000 species of invertebrates level (Ministry of Natural Resources and Environment Malaysia, 2015). However, this diversity is being threatened by agricultural expansion, logging, overhunting, housing and many more. Malaysian forest biodiversity comprises of lowland evergreen forest, lowland dipterocarp forest, heath forest, limestone forest, mixed dipterocarp forest, hill dipterocarp and hill mixed dipterocarp forest (Ministry of Natural Resources and Environment Malaysia, 2015). Oil palm and rubber are the two most important agricultural crops for Malaysia that provide providing employment and income. Malaysia's land cover has decreasing day by day.

Borneo is the world's third largest island with 745,000 km² that once covered with dense rainforest. According to Wikramanayake et al. (2002), Borneo can be divided into seven ecoregions which are Borneo peat swamp forests, Southern Borneo freshwater swamp forests, Sundaland heath forests, Borneo montane forests, Borneo lowland rainforests, Sunda shelf mangroves and Kinabalu montane alpine meadows. Borneo's intact forest is facing deforestation where 30.2% forest loss in four decades can be detected from the year 1973 (558,060 km²) to the year 2010 (168,493 km²) according to Gaveau et al. (2014). Deforestation occurred mainly in Borneo's coastal lowlands (<500 m asl) with more than 97% (164,644 km²) area (Gavaeu et al., 2014). Borneo is home of 693 bird species with 48 endemic species (Avibase, 2019). Borneo provided an avian with abundant food resources for example fruits, insects, figs, microinvertebrate and many more but due to deforestation, forest destruction and urbanization, these resources depleted each day. The main factor for

rapid forest destruction is a large scale, conversion to plantations, illegal logging and forest fires (Rautner et al., 2005). Approximately 6.5 million ha of land in Kalimantan faced forest fires between the years 1997-1998 (Rautner et al., 2005).

Oil palm plantation expanded in Sabah and Sarawak from 186,774 ha (1960) to more than 1,673,721 ha (2003). In Kalimantan, the expansion occurred even more rapid with 13,140 ha at year 1984 to nearly one million hectares at the end of 2003 (Butler, 2013). Logging in Borneo is the most notorious and vigorous (Butler, 2013). This exceeds logging in Amazon with 23 m² wood extracted (Butler, 2013). Logging in Sabah is the main economic of socio-economic development. Logging support 65,000 employment and forestry sector contributed nearly 28% from a state total revenue during the year 2000. In Sarawak, the timber sector contributed 21% of the state's total external earnings. In Kalimantan, wood-related export is 13% of Indonesia's total export in the years 2002 (Rautner et al., 2005). Illegal logging is a problem faced both Indonesia and Malaysia. In Malaysia, during the early 1990s at least 1/3 log exports is illegal (Butler, 2013). It was a 70-75% estimated percentage of timber harvesting that illegal from East Kalimantan with \$ 100 million per year in revenue lost (Butler, 2013).

Sarawak located on the island of Borneo with 124,449.51 km² of total land area. Sarawak is rich with biodiversity of flora and fauna. Based on Forest Department Sarawak (2019), there are five types of natural forest in Sarawak with three dominant forest which is hill mixed dipterocarp forest (9.6 million ha), peat swamp forest (0.75 million ha), mangrove forest (occupying slightly more than 0.09 million ha) and the other two natural forest type is kerangas and the montane forests. Sadly, Sarawak's intact forest is become rare each day with 14.6% of intact forest left by the year 2010 (Gaveau et al., 2014). Based on Hon and Shibata (2013), major land used in Sarawak is logging, agriculture and forest plantation.

The exploitation of forest begun a long time ago at the year of 1841 is the year of colonial war. During the time of the first Rajah of Sarawak is crowned (Drummond & Taylor, 1997). During that period there was informal batter trade between China and other parts of Southeast Asia happened involving minor forest product (Smythies, 1963; Drummond & Taylor, 1997; Kaur, 1998). Value of export increased by a factor of 20 from 1860 to the 1905 level of M\$ 13,422,267 (Gould-baring & Bampfylde, 1909). At year 1940, Sarawak's value of timber is £ 3,960 (RM 1185862.85), in year 1950 is £ 348,400 (RM 73029116.40); in year 1960 is £ 5,087,530 (RM 626781467.93) (Smythies, 1963). This exploitation of forest has led to the destruction of the forest and eventually lead to habitat loss for wildlife. Sarawak forest home of 589 species of birds (Avibase, 2019) and Sarawak provided shelter and food resources to them. There are species that lived in low population density and have relatively low abundance of animal even in pristine habitat, for example, Sunda Clouded leopard (*Neofelis diardi*) that 2 individuals lived in 100 km² (Brodie & Giordano, 2012) in Borneo and Sumatra.

Disturbance of the forest has created secondary forest, agroforest, logged forest, urban landscape and many more. Most of this disturbance change the bird community and structure. This illustrated in Phillipps and Phillipps (2014) where the changing of primary forest to secondary forest can affect both tree species and bird species. As many as 1200 tree species and 220+ bird species in primary forest decreases to 80 tree species and about 60 bird species in 10-year-old secondary forest. Then, when the primary forest change to logged forest the tree species still remain the same but the bird species decreases to 160 bird species. The changing of primary forest to plantation has decreases the tree species and bird species dramatically with one tree species and 12 bird species (Phillipps & Phillipps, 2014). Based on de Iongh and van Weerd (2006) study of avian guild structure in relatively undisturbed

lowland forest site of ‘Sungai Wain Forest Reserve’ (East Kalimantan) and compared with two more disturbed lowland forest sites in the Pasir district of East Kalimantan (Pinang Jatus and Mului) showed a trend of lower proportion of understory insectivores in more disturbed sites compared to Sungai Wain, the least disturbed site that showed the largest proportion (30%) of understory insectivores. Thiollay (1997) explained in his study of composition and structure of bird communities, and the damage to forest structure in northern French Guiana (northeastern Amazonia) one year and ten years after selective logging and compared with the situation in a similar undisturbed primary forest has showed a result where among the 256 species recorded, overall bird species richness and abundance were depressed by 27–34% in the logged areas compared to primary forest. Kumar and Shahabuddin (2006) study that investigate the ecological effects of anthropogenic disturbance caused by extractive activities such as grazing and firewood collection in Sariska Tiger Reserve in India, to investigate the effects of disturbance on forest bird communities. Result showed that no significant difference in the number of recorded species and bird abundance between disturbed (extracted) and undisturbed (non-extracted) sites but bird species diversity was significantly lower in disturbed sites. Bird species composition also differed significantly between disturbed and undisturbed sites (Kumar & Shahabuddin, 2006). However disturbed forest is not entirely useless. The study of Asefa et al. (2017), for example, highlights the potential conservation value of unprotected tropical montane forests for birds in the dry evergreen Afromontane forests of the Bale Mountains, Ethiopia. They sampled across 2 years in both protected forests (characterized by low levels of cultivation, overgrazing, and logging) and unprotected forests (higher levels of disturbance). Overall result showed that species richness was 27% higher and bird abundance was 19% higher in unprotected forests but species richness and abundance of forest specialists and canopy foragers were

significantly higher in protected forests. Based on this both disturbed forest and undisturbed forest have their own advantage and importance for conservation.

Disturbance can also cause by local or indigenous people even indigenous known as protector of the forest and indigenous land declining less rapidly than elsewhere on earth (IPBES, 2019). This was showed by Borges (2007) who studied bird assemblage in Brazilian Amazon where secondary forest (young secondary growth, middle aged and old secondary forest) versus primary forest. Local people in the National Park of the Brazilian Amazon has practiced slash and burn agriculture. The result showed that young secondary growth has fewer species than old secondary and primary forest. Bird communities of young secondary forest dominated by species that usually found in open habitat. This showed that indigenous communities also effected the nature around them due to their activities.

2.3 Indigenous Communities in Sarawak and Borneo

Indigenous people inhabited areas that always occur simultaneously with world remaining major concentration of biodiversity with estimated 22% of the world land surface were territory of traditional indigenous communities and they coincides with area that hold 80% of the planet's biodiversity (WRI, 2005). There 11% of the world forest land are legally owned by indigenous people and communities (White et al., 2004). Nature in indigenous lands declining less rapidly than elsewhere on earth (IPBES, 2019). Several studies have highlighted contributions of indigenous peoples and local communities in limiting deforestation, however in many region many land of indigenous peoples are becoming islands of biological and cultural diversity surrounded by areas in which nature has further deteriorated (IPBES, 2019). In Sarawak, some efforts were made for example integrating indigenous resources management with wildlife conservation in Batang Ai (Horowitz,

1998). Cooperation of local people and their leaders are needed in implementing a new conservation strategy.

There are indigenous communities in Borneo that fight to protect their land, for example the Dayak Iban of Sungai Utik community in Indonesian Borneo that managed to fend off loggers and land invaders from their forest home (Pahlevi & Butler, 2019) and Indigenous community of Baram opposing Baram dam (Gan, 2013). There are local indigenous communities whose livelihood affected the environment positively where they play an important role for conservation by deliberately preserving an area within their area of shifting cultivation that called communally reserved forests (CRFs), which have a high conservation value that harbor high alpha and beta tree diversity (Takeuchi et al., 2017). In Sabah, 'Sistem Tagal' is created by local people in effort of preserving and conservation of a natural habitat (Fatimah, 2015). This system created at first to solve the shortage of freshwater fish (Foo & Mohd. Noor, 2012) and continue for conservation purpose. Due to 'Sistem Tagal', the use of natural resources and few areas is restricted for conservation purpose (Fatimah, 2015). Some communities such as in Kampung Sebandi, Sarawak, hunt for subsistence, sport and to reduce crop pest problem (Tahir, 2004). Natural ecosystem have improved under indigenous people conservation protection that inhabit them. This also showed based on recently produced map of Brazillian Amazon and Sobrevilla (2008) also mention a strong correlation between indigenous presence and the protection of natural ecosystems.

Human-wildlife conflict has been around us and local indigenous people were told that they live harmony with nature. Human population increases resulted in destruction of the forest and infrastructure development (Sukumar, 2003; Fernando & Pastorini, 2011), this led to shrinkage of habitat for some species. One of the species effected is elephant where they

need to locate food outside of the forest (Fernando et al., 2008; Kumar et al., 2010) and this caused human-elephant conflict. The conversion of forest to other land uses can result in Orang Utan entering villager's garden and raiding crops (Meijaard et al., 2011). Based on Meijaard et al. (2011), Orang utan in Kalimantan were threat by hunting and conflict killing. Estimated killing rate is between 2383 and 3882 animals killed per year on average within the lifetime of the survey respondents in Kalimantan (Meijaard et al., 2012).

Sarawak is multicultural society with many ethnic groups such as Iban, Kayan, Kenyah, Kelabit, Bidayuh and many more. There are also nomadic Penan population of about 400 people that live within Gunung Mulu (Khaidar, 1994). Iban people is a major indigenous people that lived in Sarawak. Based on genealogy, Iban people already settle in Sarawak for 15 generation and their migration from Kapuas, West Kalimantan to Sarawak ended three century ago (Jensen, 1974). The Iban is the largest of indigenous people in Sarawak, numbering about about 797,700 in 2016 (The Official Portal of Sarawak Data, 2018). Most Iban communities lived in longhouses but globalization factors such as market assess, migration and technology network have implication toward household economics, social network and native biodiversity (Kramer et al., 2009). Longhouses communities conducted many activities such as shifting cultivation, fishing and collecting forest produce to support their livelihood. In the past, Iban longhouses have a wasteful lifespan about 15 years before they move to another area for shifting cultivation and now government encourage Iban communities and other minority groups in Sarawak to adopted more sedentary lifestyle by building a permanent structure such as using concrete, corrugated iron and glass (Yea, 2002).

2.4 Distribution of Birds in Different Forest Types of Borneo

The species distribution both influence by abiotic conditions, for example, suitable climate, and biotic conditions, for example, competitive interspecific interactions, as well as movement behaviour, such as dispersal or colonization (Soberon & Nakamura, 2009). The distribution of Bornean birds is influenced by habitat, altitude and geological and climatic history and the distribution is not uniform across Borneo. As time passed, the distribution of bird has been disrupted by disturbance that causes by logging, fragmentation, deforestation, settlement and urbanization. Disturbance of forest have a different effect towards different species. Cleary et al. (2007), studied bird species composition within a logging concession in Central Kalimantan, Indonesian Borneo found out that logging appeared to have the strongest negative effect on hornbills, terrestrial insectivores, and canopy bark-gleaning insectivores while moderately affecting canopy foliage-gleaning insectivores and frugivores, raptors, and large species in general. Meanwhile, undergrowth insectivores responded positively to logging while most understory guilds showed little pronounced effect (Cleary et al., 2007). There are some of the species that affected to logging, fragmentation and hunting (Lambert & Collar, 2002). Species such as *Argusianus argus* and the hornbill *Buceros rhinoceros* were rare or absent in recently logged forest (Cleary et al., 2007).

Based on Phillipps and Phillipps (2014), there is some bird inhabited a certain type of vegetation or forest type (Table 2.1). This forest either natural forest such as primary forest and man-made such as oil-palm plantation. Both of this two type of forest support different type of birds. Bird community in each of the vegetation or forest type is somehow differ because some of the birds have to live in specific habitat for example Bornean bulbul that confined to secondary growth and forest edge in the mountains and Pale-faced bulbul where the bulbul live in higher mountains of Borneo generally found in upper montane forest

(Phillipps & Phillipps, 2014). Some opportunist such as Yellow-vented bulbul can live in town garden and cultivated areas even in hill and mountains (Phillipps & Phillipps, 2014).

Table 2.1: Vegetation types and typical bird that inhabits it based on Phillipps and Phillipps (2014)

Type of vegetation	Description	Bird life
Primary lowland forest (0-300 m)	The richest ecosystem in Borneo dominated by giant dipterocarp trees with high diversity of plants, mammals, birds and insects.	220+ resident birds. Inhabited by lowland specialist such as Bornean ground cuckoo, Great Slaty woodpecker, Blue-headed pitta, Bonaparte's nightjar and Bristlehead.
Logged primary lowland forest	Logging activities had changed the structure of the forest allowing a secondary growth of vine and scrubs.	Insect-eater (pittas, trogons, babblers and flycatchers) declined. Berry-eaters and nectarivores increased (bulbuls, leafbirds, flowerpecker and sunbirds)
Hill and submontane forest (300-900 m)	As altitude increases, the tree height and bird diversity decrease.	Residents include Bulwer's Pheasant, Orange-breasted trogon, Hose's broadbill, Banded and Blue-banded pittas.
Montane forest (900-1,800 m)	At 900m bird and vegetation change thoroughly. Engulf by cloud by the afternoon, the moss forest dominated by oaks and laurels covered in epiphytes.	Montane birds
Upper montane forest (1,800-3,500 m)	As altitude increase, endemism also increases but bird species showed decreases. This type of forest is short and home for berry-bearing bushes.	Birds included Island thrush, Black-eye, Friendly warblers, Pale-faced bulbul and Fruithunter.
Peat swamp forest	Located in the coastal lowland and growing out of swampy peat, some trees have stilt and air breathing roots.	Birds include Wrinkled hornbill, Hook-billed bulbul, Grey-chested Jungle flycatcher, Scarlet-breasted flowerpecker, Fiery minivet and Abbott's babbler.
Kerangas or heath forest	Kerangas is a forest that grow on nutrient-poor white sand soil that not suitable for agricultural activities. Bird life here is not rich. The forest is scattered across Borneo and common in South Kalimantan.	Characteristic birds include Grey-chested jungle flycatcher, White-chested babbler, Hook-billed bulbul and Thick-billed flowerpecker.

Table 2.1 continued

Freshwater swamps, rivers and lakes	Have a large area across Borneo such as Mahakam, Kapuas, Barito, Baram and the Kinabatangan river. Lakes include natural and man-made for supply of water and electricity.	Heron, egrets, bitterns, storks, darters and other waterbirds.
Mangrove forest	Coastal forest that grow out of muddy river estuaries surrounding by brackish water.	Birds included Ruddy kingfisher, Great tit, Mangrove Blue flycatcher, Mangrove whistler, Lesser adjutant, herons and Migrant waders.
Padi fields	Lack of freshwater habitat has limited waterbird population in Borneo but recently the booming of irrigating padi fields in north west Borneo has increasing the population of migrant waterbirds	Common moorhen, Purple swamphen, Yellow bittern and Egrets.
Secondary forest and tree plantations	Huge area of the lowland forest is replaced by tree plantations in Borneo, some insectivorous birds survived adjacent to native forests.	Magpie robin, Spotted-necked dove, Glossy starling, Woodswallow, Geater and Lesser coucals.
Oil palm plantations	There has been a rapid conversion of lowland and peatswamp forest into oil palm plantation in Borneo. About 14 species of bird breed and survive in oil palm plantation.	Birds include Scaly-breasted, Dusky and Chestnut munias, Prinia, Magpie robin, Spotted-necked dove, Owls, Yellow-vented bulbul, Pied fantail, White-breasted waterhen, Emerald dove, Olive-backed and Brown-throated sunbirds.

2.5 Bulbul

Bulbul is a passerine songbird that is often acknowledged in Persian poetry, remarked as nightingale. Bulbul (Family Pycnonotidae) has 162 species worldwide (IUCN, 2020), 68 species in Southeast Asian (Avibase, 2019) and 27 in Borneo (Avibase, 2019). There are several studies conducted by researchers in Borneo Island that have recorded bulbul (Table 2.2). This study showed bulbul list that caught in different site in Borneo.

Table 2.2: Bulbul list from different study in Borneo

Source	Site	Bulbul list
Burner et al. (2016)	Gunung Mulu np	Straw-headed bulbul
		Black and white bulbul
		Cream-vented bulbul
		Asian Red-eyed bulbul
		Spectacled bulbul
		Finsch's bulbul
		Ochraceous bulbul
		Grey-cheeked bulbul
		Yellow-bellied bulbul
		Hook-billed bulbul
		Hairy-backed bulbul
		Buff-vented bulbul
		Streaked bulbul
		Pale-faced bulbul
Tuen et al. (2018)	Upper Balleh	Buff-vented bulbul
		Finsch's bulbul
		Hairy-backed bulbul
		Black-headed bulbul
		Olive-winged bulbul
		Red-eyed bulbul
		Scaly-breasted bulbul
		Spectacled bulbul
		Grey-bellied bulbul
		Grey-cheeked bulbul
		Yellow-bellied bulbul
		Black and White bulbul
Sheldon et al. (2013)	Kelabit highland	Straw-headed bulbul
		Black and white bulbul
		Black-headed bulbul
		Bornean bulbul
		Puff-backed bulbul
		Yellow-vented bulbul
		Pale-faced bulbul
		Olive-winged bulbul
		Cream-vented bulbul
		Red-eyed bulbul
		Spectacled bulbul
		Ochraceus bulbul
		Grey-cheeked bulbul
		Yellow-bellied bulbul

Table 2.2 continued

		Streaked bulbul
		Buff-vented bulbul
		Cinereous bulbul
		Hairy-backed bulbul
van-Balen and Prentice (1996)	Sungai Negara, Kalimantan	Black-headed bulbul
		Yellow-bellied bulbul
		Olive-winged bulbul
Sheldon et al. (2009)	Klias Forest Reserve, Sabah	Hook-billed bulbul
	Ulu Rukuruku and Meliau, Sabah	Black and white bulbul
		Grey-checked bulbul
	Meliau, Sabah	Grey-bellied bulbul
		Streaked bulbul
	Ulu rukuruku ,Sabah	Yellow-bellied bulbul
	Trus madi, Sabah	Flavescent bulbul
	Ulu Laubon, Sabah	Olive-winged bulbul
	Meliau Basin	Buff-vented bulbul
	Kinabatangan and Danum Valley, Sabah	Straw-headed bulbul

Based on Phillipps and Phillipps (2014), there are two endemic species of bulbuls in Borneo, these are the Bornean bulbul (*Pycnonotus montis*) that occur in the south to Barito Ulu, Kalimantan and locally common in Crocker Range, Rafflesia Centre, Sabah and scarce on Kinabalu, Sabah. Bornean bulbul is restricted to secondary growth and forest edge in the mountains at 600-1500 m. Pale-faced bulbul/Ashy bulbul (*Pycnonotus leucops*) is a higher montane endemic that restricted to upper montane forest. This bulbul is common on Kinabalu Summit Trails, summit of Gunung Tambayukon, Gunung Trus Madi (Sabah) and Gunung Mulu (Sarawak). Bulbuls also inhabited a wide range of habitat and few bulbul inhabit specific habitat as described by Phillipps and Phillipps (2014) in Table 2.3.

Table 2.3: Habitat preference of bulbul of Borneo based on Phillipps and Phillipps (2014)

Bulbul list	Habitat preference
Straw-headed bulbul (<i>Pycnonotus Zeylanicus</i>)	Common in forested area along stream and rivers.
Maratua bulbul (<i>Pcynonotus hodiernus</i>)	Forest and in village garden
Black-headed bulbul (<i>Pycnonotus atriceps atriceps</i>)	Common in lowland primary and secondary forest.
Black and white bulbul (<i>Pycnonotus melanoleucos</i>)	Forest bird
Grey-bellied bulbul (<i>Pycnonotus cyaniventris</i>)	Very scarce but widespread in both primary and secondary forest. Prefer riverine forest.
Puff-backed bulbul (<i>Pycnonotus eutilotus</i>)	Understory of lowland primary and hill forest.
Olive-winged bulbul (<i>Pycnonotus plumosus</i>)	Coastal area, keeps to degraded scrub and the edges of secondary forest.
Yellow-vented bulbul (<i>Pycnonotus goiavier</i>)	Common in town garden and cultivated area.
Cream-vented bulbul (<i>Pycnonotus simplex</i>)	Undisturbed primary forest.
Red-eyed bulbul (<i>Pycnonotus brunneus</i>)	Logged and secondary forest.
Blue-wattled bulbul (<i>Pycnonotus nieuwenhuisii</i>)	Only three recorded. Dighting at riverside fruiting <i>Macaranga</i> s.p.
Spectacled bulbul (<i>Pycnonotus erythrophthalmos</i>)	Lowland primary and mature secondary forest.
Red-whiskered bulbul (<i>Pycnonotus jocosus</i>)	Introduced species that often kept as pets. Recorded as an occasional escape in Borneo but not established.
Sooty-headed bulbul (<i>Pycnonotus aurigaster</i>)	Bird of cultivated area and plantations.
Hairy-backed bulbul (<i>Tricholestes criniger</i>)	Locally common resident of lowland and hilly forest. Found also in mangrove, coastal, secondary and primary forest.
Hooked-billed bulbul (<i>Setornis criniger</i>)	Scarce local resident of lowland primary forest.
Streaked bulbul (<i>Ixos malaccensis</i>)	Resident in primary and secondary forest of the lowland and hills.
Yellow-bellied bulbul (<i>Criniger phaeocephalus</i>)	Inhabitant of primary forest and logged forest from the coast to the hills.
Buff-vented bulbul (<i>Iole olivacea</i>)	Prefer secondary and logged forest. Uncommon resident of lowland and hill forest.

Table 2.3 continued

Finsch's bulbul (<i>Criniger finschii</i>)	Common resident of lowland and secondary forest with preference for hilly or submontane areas.
Grey-cheeked bulbul (<i>Criniger bres</i>)	Common of lowland primary forest, also in hills and wander into the mountains,
Ochraceous bulbul (<i>Criniger ochraceus</i>)	Common throughout mountain in Borneo
Cinereous bulbul (<i>Hemixos cinereous</i>)	Common resident of hills and mountains. Occasionally in lowland.
Pale-faced bulbul (<i>Pycnonotus leucops</i>)	Common of higher mountains of Borneo generally found in upper montane forest.
Scaly-breasted bulbul (<i>Pycnonotus squamatus</i>)	Rare but widespread. Nomadic of submontane primary and secondary forest.
Bornean bulbul (<i>Pycnonotus montis</i>)	Confined to secondary-growth and forest edge in the mountains (600-1500 m)

Breeding biology of animal is influenced by many factors such as food supply, predation risk and nest site selection (Newton, 1998). Breeding biology influenced by food supply as stated by Fogden (1972) where two bulbul species at Semengo Forest Reserve had suppressed their breeding activity in low fruit abundance year than in high fruit abundance year. The proportion of juveniles in the population was seven fold higher in high fruit abundance year (14%) than in low fruit abundance year (2%). There is a study by Krüger (2004) comparing the differences in breeding biology of Cape bulbul (*Pycnonotus capensis*) between his study and study made by Liversidge (1970) with 40 years gap. The study showed no differences in the timing of breeding, clutch size, number of fledging per nestling attempt or successful nesting attempt. This indicated that no massive shift in life history strategy or breeding success.

Many questions arise as to why bulbul have a good distribution and one of the reason is flexible nesting site (Li et al., 2015; Aslan et al., 2018) where the tested species build nest in cultivated landscape, garden, maquis grove, bushes and small tree in human habitation.

However, there are certain species that are selective when choosing their nesting site. For example, Hsu and Lin (1997) reported Styan's bulbul (*Pycnonotus taivanus*), which is an endemic species in Taiwan, selected their nesting site among dense vegetation. Most of the nest (75% with n = 84) were found in Indiapoon Beautyleaf tree *Calophyllum inophyllum* which had a relative vegetation density of only 33.5%. There are also bulbul species such as the Grey-headed bulbul (*Brachypodius priocephalus*) that is restricted only to mid elevation evergreen forest (700-1400 m) during breeding season (Balakrishnan, 2007). This species is found in the Western Ghats and Palni Hills in South-West India (del-Hoyo et al., 2005) and listed as near threatened because of moderately rapid population decline due to habitat losses and forest degradation throughout its range (del-Hoyo et al., 2005; Balakrishnan, 2007; Birdlife International, 2018). Balakrishnan (2011) studied in Silent Valley National Park, Western Ghats, India in year 2003 to 2005 showed that all nests were found in mid-elevation evergreen forest that ranged in elevation from 900 m to 1400 m. Breeding happen in drier month during January to May where the fruit availability is high. Overall nest success in this study was 10.79% but nest success varied among incubation and nestling periods. This species displayed life-history traits linked with low productivity such as short breeding season, low clutch size, fewer brood per year and high predation showing that declining of breeding habitat will affect the long-term survival of the species.

Bulbul is one of the successful birds due to many reasons. One of the reasons is bulbul does not interfere with other species (Bates, 2011). Bates (2011) studied the foraging behavior partitioning and interaction between two invasive species, which is Common myna and Red-vented bulbul. His outcome indicated that both species tend to avoid competition between them making them both a successful invasive species. Bulbul also fed on introduced species to adapt to their surroundings. Yellow-vented bulbul that live in oil palm agroecosystem

seem to select their food from coleopteran family curculionidae (introduced pollinating weevil, *Elaeodabius kamerunicas*) (Amit et al., 2015).

Bulbul's success is contributed also by being able to feed on wide range of food. Red-whiskered bulbul is an opportunistic bird which consumed a wide range of fruits, buds, insect (Carleton & Owre, 1975; Van Riper et al., 1979) and nectar (Olesen et al., 1998) enabling them to survive in area where fruit is seasonally available and make them excellent invaders (Corlett, 1998b). Bulbul relatively large maximum gape widths for their size (12-13 mm in birds 190 mm long for Hong Kong species) allow them to eat wide range of fruits and flexible diet (nectar and flycatching) making them a survivor in area where fruit is available seasonally (Corlett, 1998b).

2.6 Diet of Bird and Bulbul

Diet is the kind of foods that is habitually eaten by human or animal. Knowledge of bird diet types is important for us to understand bird ecology, feeding guilds, feeding habits and environment. According to Lopes et al. (2016), there are 23 food categories that are eaten by birds and the study also provided terminology for classifying avian diets (Table 2.4).

There are also unusual food items that do not justify the recognition of a distinct food categories, something that less important in the sense of food item that are taken rarely such as tree bark, sea urchins, starfishes and many others (Lopes et al., 2016). One example is oxpeckers (*Buphagus* spp.) that consume body fluid out of nose and ear wax of ungulates (Bezuidenhout & Stutterheim, 1980). Birds also consumed non-food material that do not have any nutrition value, for example grit and gravel that are used to grind food (Gionfriddo & Best, 1999). They also provided a solution for birds that eat different range of food categories using arbitrary breaking points to delimit distinct diet type. For example, species

that feed on both insect and fruit can be classified as insectivore, insectivores secondarily frugivores, frugivores-insectivores, frugivores secondarily insectivores and frugivores (Lopes et al., 2016).

Table 2.4: Feeding guild of birds according to Lopes et al. (2016)

Diet type	Food categories
Algivore	Macroscopic, non-planktonic algae
Cerivore	Wax from bee honeycombs. Animal that feed on wax often called wax-eaters or cerophagous.
Exudative	Plant fluid for example sap, gum and resin.
Ilivore	Consume organic mud and associated microbiota inside mud (bacteria, protozoa and algae)
Folivores	Leaves, stems, shoots, and buds, flowers, whole aquatic plants, ferns, clubmosses and mosses.
Frugivores	Fleshy fruits (Berries, drupes, pomes, aggregated fruits, multiple fruits and accessory fruits.
Fungivore	Fungus and lichens.
Granivore	Seeds, grains, nuts and dry fruits (pines, grasses, sedges, composites, oaks and palm).
Nectarivore	Nectar of flowers
Palynivores	Pollens. Animals that feed on pollen sometimes called pollinivorous.
Phytoplanktivore	Microscopic algae such as diatoms and cyanobacteria that obtained by filter-feeding
Radicivores	Storage organ of plants. This usually in a form of carbohydrates for example tuberous roots, taproots, corms, stem tubers, rhizomes and bulbs.
Carnivores	Tetrapoda (amphibians, reptiles, birds and mammals). Egg of tetrapodes also included in this food categories.
Coprovore	Excreta of animals.
Crustaceovore	Non-zooplanktonic crustacea, such as non-larval Malacostraca for example crabs, lobsters, crayfishes, shrimps, prawns, mantis-shrimps, barnacles and goose barnacles). Terrestrial crustacea also included in this categories.
Insectivore	Hexapoda (insects and their kin), terrestrial arthropods (ticks, spiders) and Myriapoda (centipedes and millipedes).
Molluscivore	Mollusks (Chitons, slugs and squids).
Scavenger	Carcasses of vertebrates, scraps of food seized from predators and other dead tissues.

Table 2.4 continued

Piscivore	All kind of fish. Fish must be captured alive and fish egg also included in this categories.
Hermatophagous	Blood of tetrapods, as well as consumptions of damaged tissues.
Vermivore	All muinds of “worms” including Platyhelminthes, Nemertea, Annelida, Nematoda and Priapulida among others.
Zooplanktivore	Plantonic animals (larvae of glassworms, krill, brine-shrimps, copepods, forams and plantonic larval stage of many others animal.
Purgamenovore	All kind of processed food produced by humans.

There are many factors influencing diet type in birds, typically based on age-related, sexual, seasonal, geographic variation and stage of growth (Lopes et al., 2016). Wheelwright (1985) investigate gape limitation and their influence on fruit-eating birds. Broad-gape fruit-eating bird consumed a larger mean and maximum size of fruits compared to narrow-gaped birds (Wheelwright, 1985). However, smallest size fruits eaten was not correlated with gape width as large-gaped species usually feeds on extremely small fruits (Wheelwright, 1985). Bill size and shape give information regarding bird’s lifestyle and preferred diet (Hessel, 2008). This shown by egret or heron with spear-shaped bill that facilitate hunting in shallow water; Nightjar that scoop insect at night where precision is out of context at night; Whimbrel with long curved bill that allow the bird probe deep into the mud.

Bulbul is a generalist frugivores that feed on broad type of fruits (Fukui, 1995; Corlett, 1998a). Some of the bulbul also feed on broad type of food, for example Red-whiskered bulbul that consume wide range of fruits, buds, insect (Carleton & Owre 1975; Van Riper et al., 1979) and nectar (Olesen et al., 1998). This is their strategy that enable them to survive in area where fruit is seasonally available and make them an excellent invaders (Corlett, 1998a). Based on Kerdkaew et al. (2014), *Pycnonotus brunneus* and *Pycnonotus goiavier* are highly frugivorous with little insectivory especially when it is out of breeding season.

This change of diet is due to protein-demanding breeding process (Ward, 1969). This was also observed in *Pycnonotus sinneus* where insect intake increases 1.8% to 55% during breeding. Red-whiskered bulbul changed their diet according to nesting time where invertebrates decreases while plant food increases according to nestling age (Li et al., 2015). Montane bulbul starting up their cool morning day with sugar rich high energy fruits and eat wide variety of food later in the day (Davison, 1992).

Bulbul are important agents of seed dispersal and germination of plant (Corlett, 1998a; Linneberg et al., 2010; Kerdkaew et al., 2014), they eat whole fruit and germinate better (Linneberg et al., 2009; Kerdkaew et al., 2014). Bulbul are often introduced in many places such as Mauritius, Reunion Island and Mo'orea as caged bird (Mandon-dalger et al., 2004; Linneberg et al., 2009; Linneberg et al., 2010). They feed both on native and exotic plant that can causes harm to the environment as they often invading non-invaded habitat and pollinate and disperse exotic plants (Simberloff & Von Holle, 1999; Goulson, 2003; Mandon-Dalger et al., 2004). Red whiskered bulbul has been introduced to many places such as Mauritius and Reunion Island. This introduced bulbul eats a large portion of introduce plant with 53% in Mauritius and 87% in Reunion Island (Mandon-dalger et al., 2004; Linneberg et al., 2009). *Lingustrum robustum* and *Clidemia hirta* are two of the many invasive plant that are consumed by Red-whiskered bulbul (Linneberg et al., 2009). Gut passage of introduced *Clidemia hirta* seed in Mauritius germinated by bulbul faster than hand cleared seed with a higher overall germination success against manually de-pulp control seeds and none of intact fruits germinate.

CHAPTER 3

MATERIALS AND METHODS

3.1 Study Site

This study was conducted in the Pelagus district, Kapit division, Sarawak, Malaysia Borneo. The main ethnic group inhabiting this area is the Iban. Their main socio-economic activities are farming, fishing and hunting.

The study site was the disturbed forests behind three Iban longhouses, which are Rumah Laja, Rumah Bujah and Rumah John. The sampling stations were located 100, 500 and 1000 m away from each longhouse. The sampling stations were located along existing forest trail and the distance of each sampling station from the longhouse was measured using a measuring tape. These trails were chosen because we want to study the effect of local people toward the wildlife and because the trail was generally used by the local community for their routine activities. The maximum distance of 1000 m was chosen in this study because there was an agreement between longhouse communities with logging company which banned logging activities within 1000 m from longhouses. If the sampling site go beyond 1000 m, this will show the effect of logging instead of the effect of longhouses communities.

Three forest types occur in Pelagus – the original mixed dipterocarp forest, agroforest and secondary forest. The original dipterocarp forest has been logged commercially as early as 1960s. Even before commercial logging was carried out in Pelagus, the Iban community had been practicing their traditional shifting cultivation to plant padi which is their staple food. After harvesting their padi the Iban would often plant fruit trees and other agriculture crops which then grow together with wild plants, creating an ecosystem known as agroforest. Agroforest is a collective name for land-use systems where woody perennials (trees, shrubs,

palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence (FAO, 2015). Secondary forests are regenerating forest largely through natural processes after significant removal or disturbance of the original forest vegetation by human or natural causes at a single point in time or over an extended period, and displaying a major difference in forest structure and/or canopy species composition with respect to pristine primary forests (Liss et al., 2003). Meanwhile logged forest is an area of forest that had been logged before.

Pelagus National Park (PNP) site was the designated control site in this study because it is a totally protected area in which all forms of anthropogenic activities is illegal without a permit. The distance of Pelagus National Park sampling station to Rumah Laja is 6.6 km; Rumah John is 3.1 km; Rumah Bujah is 2.0 km. Only one sampling station was in PNP. Table 3.1 showed a habitat characteristics of Pelagus National Park and all stations.

Table 3.1: Habitat characteristics of all sampling stations. Abbreviation: 0 = absent; 1 = present. Source of data: Pang (2020)

Parameters	PNP	RL1	RL2	RL3	RJ1	RJ2	RJ3	RB1	RB2	RB3
Average canopy gap (%)	89.2	94.9	95.7	92.9	87.1	87.2	82.3	91.2	91.9	93.6
Average temperature (°C)	28.4	33.1	27.5	30.4	27.6	47	30.3	30.8	28.7	31.0
Average relative humidity (%)	83.3	70.4	91.1	76.1	90.4	87.8	81.6	80.1	80.0	71.8
Average light intensity (lux)	477.8	2118.7	412.8	4944.5	2302.8	412.8	844.7	4329	1114.8	408.5
Average of depth of leaf litter (cm)	7	6	7	3	7.5	7	6	4.5	2.5	9.5
Presence of human	0	0	0	0	1	1	0	0	0	0
Presence of domestic animal	0	0	0	0	1	1	1	0	0	0
Total number of wild trees	15	6	18	7	0	2	19	12	15	19

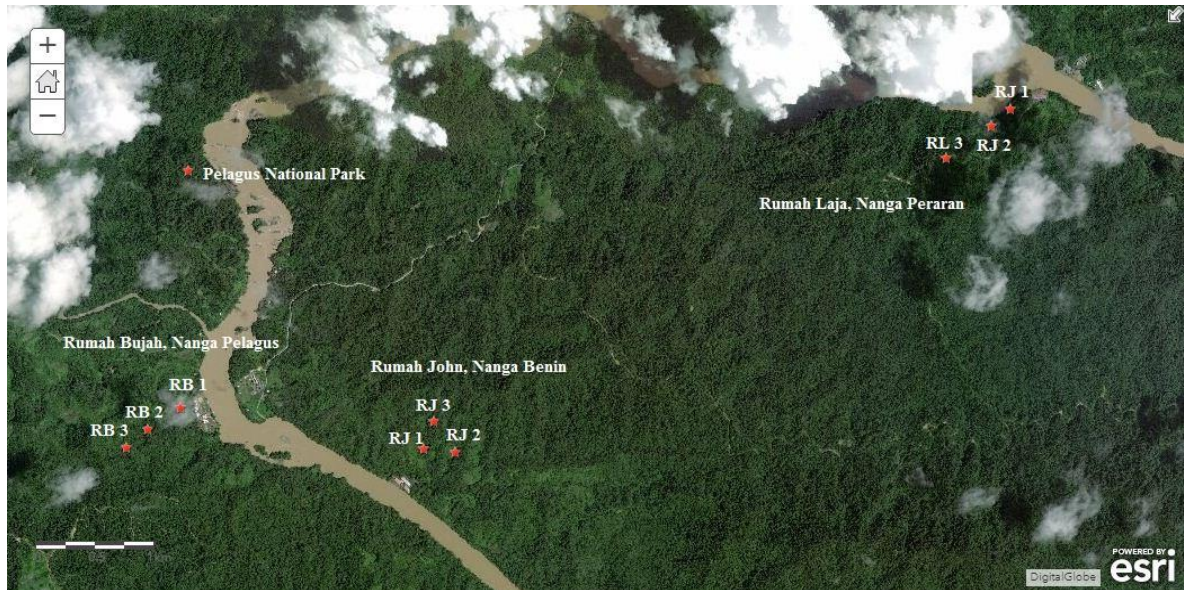


Figure 3.1: Map showing location of sampling stations for Rh Laja, Bujah, John and in PNP
Source: ArcGIS online

3.1.1 Rumah Laja

Rumah Laja is located at Nanga Peraran (N 02°11'38.86" E 113° 7'13.33") with maximum elevation of 38 m. Their forest consists of agroforest, secondary forest and logged forest. Anthropogenic activities conducted by locals include farming, collection of forest produce and hunting for wildlife. Local people used the land adjacent to their longhouse for planting rice, vegetable and fruits. Domestic animals such as dogs, cats, chicken and pigs were reared. Wildlife such as frog, python and porcupine were the example of animals collected by the locals for consumption. They also collected wild plant such as mushroom, fern and rattan from the forest and planted edible fruits tree such as durian, rambutan and cempedak. They used the river behind their longhouse for water supply that connected to their longhouse via gravity feed system. Arenga sp., rubber (*Hevea brasiliensis*), Macaranga sp., Antidesma sp and *Macaranga costula* can be found around Rumah Laja. The dominant species were Macaranga sp with 6 tree count and 4 cm average DBH (diameter at breast height). Sampling

station at Rumah Laja were labelled RL1, RL2 and RL3 respectively for stations located at 100 m, 500 m, and 1000 m from the longhouse.

Table 3.2: Forest type and description at Rumah Laja

Stations	Forest type	Description
RL1 (100 m)	Agroforest	RL 1 have agroforest where all other scrub or local tree have emerged among fruit crops and woody perennials, for example durian, rambutan, bamboo and dabai.
RL2 (500 m)	Secondary forest	RL 2 is secondary forest due to previous shifting cultivation activities.
RL3 (1000 m)	Logged forest	RL 3 is categorized as logged forest where the logging road and signs of past logging can still be seen.

3.1.2 Rumah John

Rumah John is located at Nanga Benin (N 02°0 9'52.84" E 113° 4'19.98"). Maximum elevation for Rumah John is 79 m. The locals used the Benin River near their longhouses as their main sources of water supply. They also use this river for bathing, washing, fishing, cooking and drinking. Anthropogenic activity can be observed in nearby forest as it was easy to assess. These activities include hunting, gathering forest produce and agriculture. Secondary and agroforest can be observed at this site. At Nanga Benin, there were several tree species, which include *Arthocarpus komendo*, *Ficus franciscii*, *Pangium edule*, *Dillenia suffructicosa*, *Ilex* sp, *Lithocarpus* sp., *Macaranga* sp. and *Mallotus leucodermis*. *Mallotus leucodermis* was the dominant tree species with 4 trees and DBH average of 21.75 cm. There are three longhouses in Nanga Benin but Rumah John was chosen as representative. Stations at Rumah John were labelled RJ1, RJ2 and RJ3 respectively based on distance of 100 m, 500 m, and 1000 m from the longhouse (Table 3.2).

Table 3.3: Forest type and description of sites at Rumah John.

Stations	Forest type	Description
RJ1 (100 m)	Agroforest	RJ 1 have agroforest where all other scrub or local tree have emerged among fruit crops and woody perennials for example durian, rambutan and rubber tree.
RJ2 (500 m)	Agroforest	RJ 2 have agroforest where all other scrub or local tree have emerged among fruit crops and woody perennials include palm.
RJ3 (1000 m)	Secondary forest	RJ 3 is secondary forest due to previous shifting cultivation activities can be observed.

3.1.3 Rumah Bujah

Rumah Bujah (N 02° 10' 15.83" E 113° 3' 19.57") is located at Nanga Pelagus (maximum elevation: 42 m). Locals here depended on a nearby stream (un-named) as their source of clean water to drink, cleaning and cooking. They fish at Batang Rajang, setting up their fishing nets at Pelagus rapid so they can catch fish to sell in Kapit town and for self-consumption. In the forested area behind their longhouse they have planted fruit trees such as durian, mata kucing and rambutan. They also planted vegetable such as cucumber, pumpkin and chillies, and rear domestic animals such as dog, cat and pig. Wildlife such as wild pig, deer, bats and frogs were collected for consumption. There were two types of forest at this site, agroforest at 100 m and 500 m and secondary forest at 1000 m. *Havea brasiliensis*, *Dillenia suffruticosa*, *Macaranga* sp., *Ficus* sp and *Pongamia edulis* are tree species that can be found at Rumah Bujah. This site was dominated by *Dillenia suffruticosa* with 9 trees and average DBH of 4.93 cm. Sampling stations at Rumah Bujah were labelled RB1, RB2 and RB3 respectively based on distances of 100 m, 500 m, and 1000 m from longhouse.

Table 3.4: Forest type and description at Rumah Bujah

Stations	Forest type	Description
RB 1 (100 m)	Agroforest	RB 1 have agroforest where all other scrub or local tree have emerged among crops and woody perennials for example durian, rambutan and cempedak.
RB 2 (500 m)	Agroforest	RB 2 have agroforest where all other scrub or local tree have emerged among fruit crops and commercial plant include rubber, pepper plant and durian.
RB 3 (1000 m)	Secondary forest	RB 3 is secondary forest due to previous shifting cultivation activities can be observed.

3.1.4 Pelagus National Park

The sampling station at Pelagus National Park (N02°11'24.00" E113°03'36.00") was located next to the Pelagus rapid, with maximum elevation of 148 m above sea level and can be reached using small boat. Pelagus National Park was gazette at 26 February 2009. The terrain was hilly with steep slope. The standout trees in Pelagus National Park include *Anisophyllea disticta*, *Aporosa* sp., *Baccaurea macrocarpa*, *Brownlowia cuspidata*, *Diallum indum*, *Ficus* sp., *Elateriospermum tapos*, *Hopea* sp. and *Macaranga* sp. *Macaranga* is the dominant plant group at the sampling station with 8 trees averaging 17 cm DBH. This is because our sampling station was along the trail leading to an abandoned telecommunication station located about 400 m on a hill behind the abandoned Regency Pelagus Resort (Figure 3.2). This resort closed in January 2012. This site assumed to be undisturbed because activity here is regulated under National Park and Nature Reserves Ordinance 1998 and used as control site.



Figure 3.2: One of the block at Regency Pelagus Resort. The sampling site in Pelagus National Park was located in the forest about 150 m behind the resort (arrowed). This resort abandoned since January 2012

3.2 Sampling Design

Rumah Laja, Rumah John and Rumah Bujah were the three replicates sites. In order to test for effect of disturbance originating from the longhouse, sampling stations were located in the disturbed forest about 100 m, 500 m and 1000 m from each longhouse. The main treatment is the distance from the longhouses. In this design the sampling location nearest to the longhouse is regarded as the most disturbed while the one furthest is least disturbed based on human accessibility due to distance. The sampling site located within Pelagus National Park was used as control because it is a totally protected area and experienced very little human activity since the resort closed in 2012. Each sampling site was visited four times in a year. The first trip was conducted during December 2014-January 2015, followed by March and April 2015 for second trip, August 2015 and November 2015 for the third and fourth trip.

Table 3.5: Sampling dates for Pelagus National Park and all stations

Site/Trips	Trip 1 (December 2014-January 2015)	Trip 2 (March-April 2015)	Trip 3 (August 2015)	Trips 4 (November 2015)
RL 1	6 to 9 January 2015	25 to 28 March 2015	12 to 15 August 2015	3 to 6 November 2015
RL 2	6 to 9 January 2015	25 to 28 March 2015	13 to 16 August 2015	3 to 6 November 2015
RL 3	6 to 9 January 2015	25 to 28 March 2015	13 to 16 August 2015	4 to 7 November 2015
RJ 1	12 to 15 December 2014	4 to 7 April 2015	22 to 25 August 2015	17 to 20 November 2015
RJ 2	13 to 16 December 2014	4 to 7 April 2015	22 to 25 August 2015	17 to 20 November 2015
RJ 3	13 to 16 December 2014	4 to 7 April 2015	22 to 25 August 2015	17 to 20 November 2015
RB 1	12 to 15 January 2015	30 march to 2 April 2015	17 to 20 August 2015	9 to 12 November 2015.
RB 2	12 to 15 January 2015	31 march to 3 April 2015	17 to 20 August 2015	8 to 13 November 2015
RB 3	12 to 15 January 2015	31 march to 3 April 2015	17 to 20 August 2015	8 to 13 November 2015
Pelagus National Park	10 to 13 December 2014	4 to 7 April 2015	14 to 17 August 2015	8 to 11 November 2015

3.3 Avifauna Sampling Method

Bird sample was collected by mist netting method (Figure 3.3). Mist-netting is commonly used to document differences in abundance indices among species, locations, years or age classes and to detect trend in population studies over the long term (Dunn & Ralph, 2002). Mist nets can sample species that are poorly detected by other means, data is not observer bias and netting effort easily standardized and the birds caught examined using hand (Dunn & Ralph, 2002). Two single mist nets of mesh-sized of 36 mm were stacked together with a length of 9 m and 3.6 m height at the highest point of shelf. A total of 16 mist nets was set

up at each sampling stations (included Pelagus National Park) for four days with 3072 net hours of sampling effort. Mist net was checked every two hours between 7 am to 6 pm each day. The captured bird was placed in cloth bag, measured, weighed, identified based on Phillipps and Phillipps (2014) and Myres (2009), ringed and then released near the site of capture. Dead birds were preserved and labeled as voucher specimens.



Figure 3.3: Setting up mist net

3.4 Dietary Assessment

3.4.1 Survey of Potential Food Resources

3.4.1.1 Fruit Survey

Five fruit nets, 1 m² in size, constructed from plastic mesh, sticks and PVC pipe support that inspired by Wright et al. (1999), Harms et al. (2000) and Muller-Landau et al. (2002). Nets were set randomly at distance of 100, 500 and 1000 m from the respective longhouses and in Pelagus National Park, and located near to trails to our mist nets. The fruit nets were deployed after some scrubs and small trees were cleared. The fruit nets were supported with

four sticks (Figure 3.4). The fruit were collected every 10 days, dried, weighed and identified using local names.



Figure 3.4: Fruit nets. The fruit nets were supported with four sticks, 1 m² in size constructed from plastic mesh, and PVC pipe support

3.4.1.2 Invertebrate Survey

The invertebrate survey was conducted using pit fall trap and sticky trap. Pit fall traps captured invertebrates that are active on the ground (Sherley & Stringer, 2016). Hole on the ground that fit- the size of pit fall traps was dug, and the pit fall traps made from plastic container was placed inside it until the top was flushed with the ground level (Figure 3.5). This study used plastic container for its low cost and easy installation. Plastic container have dimensions of 110 mm in diameter and 105 mm in height. The insects were captured after they fall into pit-fall traps. This insect traps were set up for four days and collected at the end of this period. The insects were killed in preservative solution, which was ethanol 70%, and taken back to laboratory for sorting and identification (Sherley & Stringer, 2016).

Sticky trap is a simple and effective way to capture insect. It is a passive method, just like the pitfall trap. A commercially available fly trap with dimension of 210×297 mm was used in this study. The trap was set up by tying it to the trunk of a tree near the mist net (Figure 3.6). The traps were tied to a tree near the netting station on day 1 and collected on day 4. The height of the trap above ground was about breast height which is approximately 120 cm from the ground. The identification of insect was based on Hill and Abang (2006).



Figure 3.5: Pitfall trap made from plastic container. The cover was put above to prevent rainwater from coming in but not to obstruct insect from falling in



Figure 3.6: Sticky trap. A commercially available sticky fly trap were tied around tree at about breast height, which is approximately 120 cm from the ground

3.4.2 Regurgitation

Forced regurgitation was also conducted to know what the bird eat. This method was applied immediately to the bulbul after it was captured. Forced regurgitation in bird often used emetic solution antimony potassium tartrate (e.g. Prys-Jones et al., 1974; Tomback, 1975; Poulin & Lefebvre, 1995). This study using regurgitation method described by Pang et al. (2017), where the dose was 1 ml of 1% antimony potassium tartrate per 100 g bird body weight. This was administered orally using flexible plastic tube that is attached to a syringe. This procedure was done slowly and steadily so as not to harm the bird. The bird was then put inside a plastic container (with air holes made on the top and side) and put in a dark quiet place for the next 10 minutes so that they can regurgitate their crop and stomach content. The regurgitated sample was collected and kept in a vial containing 70% ethanol solution. The regurgitated sample was later examined in the lab using microscope based on Hill and Abang (2006).



Figure 3.7: Administration of tartar emetic solution to bulbul. The bird was then put inside a ventilated plastic container and put in a dark quiet place for the next 10 minutes so that they can regurgitate their crop and stomach content

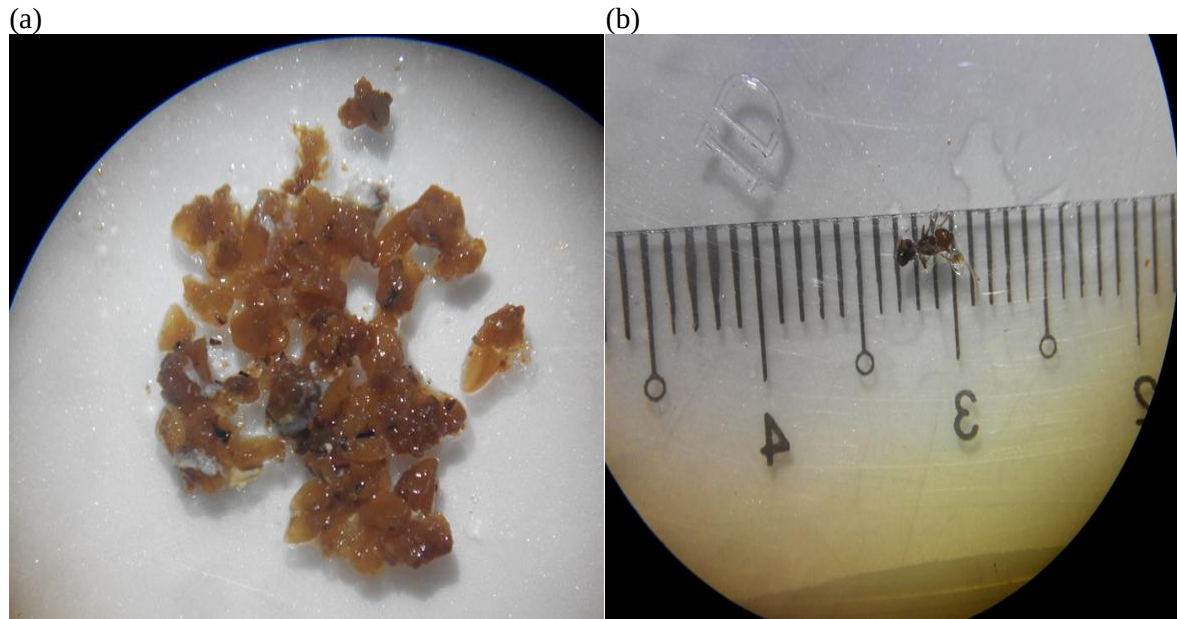


Figure 3.8: Regurgitated sample observed through microscope. (a) Unidentified plant material observed through microscope (b) Hymenoptera observed under microscope

3.5 Data Analysis

3.5.1 Species Accumulation Curve

Species accumulation curve is a curve of number of species in particular area against cumulative effort. The species accumulation curve for bulbul was plotted using the accumulated number of species captured on Y-axis against the mist netting effort (net-days) on X-axis. Another curve is the rarefaction curve in which the X-axis is the number of individuals collected from an environment and the Y-axis is the observed species richness (Gotelli & Chao, 2013). This curve rises monotonically to an asymptotic maximum number of species.

3.5.2 Species Diversity

Shannon's index and Simpson's index were calculated to estimate of species diversity. Both diversity indices were generated using Paleontological software (PAST). Shannon index was calculated using equation below. Shannon index incorporates the number of individuals of each species and also number of species in the equation.

$$H = - \sum_i \frac{n_i}{n} \ln \frac{n_i}{n} \quad \text{Equation 3.1}$$

n_i = number of individuals of species i

n = total number of organisms in all species

Simpson's index calculated also in PAST software where Simpson's index $1-D$ was used.

$$D = \sum_i \left(\frac{n_i}{n} \right)^2 \quad \text{Equation 3.2}$$

n_i = number of individuals of taxon i

n = total number of organism in all species

3.5.3 Rarefaction

Individual rarefaction was used to compare taxonomical diversity in samples of different size. Data used in this calculation are one or more columns of counts of individuals of different species. Individual rarefaction estimates numbers of species that can be expected in a sample with a smaller total number of individuals so that the number of species in samples of different size can be compared (Hammer, 2001).

Using equation below, N is the total of individuals in the sample, s is the total of number of species and N_i the number of individuals of species number i . Standard error (square roots of variances) were provided by the program and when the graph were plotted these standards error converted to 95% confidence intervals (Kreb, 1989). Equation of $E(S_n)$ is an expected number of species in a sample n and the variance $V(S_n)$ by

$$E(S_n) = \sum_{i=1}^s \left[1 - \frac{\binom{N-N_i}{n}}{\binom{N}{n}} \right] \quad \text{Equation 3.3}$$

$$V(S_n) = \sum_{i=1}^s \left[\frac{\binom{N-N_i}{n}}{\binom{N}{n}} \left(1 - \frac{\binom{N-N_i}{n}}{\binom{N}{n}} \right) \right] + 2 \sum_{j=2}^s \sum_{i=1}^{j-1} \left[\frac{\binom{N-N_i-N_j}{n}}{\binom{N}{n}} - \frac{\binom{N-N_i}{n} \binom{N-N_j}{n}}{\binom{N}{n} \binom{N}{n}} \right]$$

3.5.4 Species Richness

Species richness is a measure of number on species (or other taxonomic level) that is present at a site. Menhinick's richness index (Whittaker, 1977) and Margalef's richness index (Margalef, 1958) were generated using PAST software and both indices incorporated the size of studied sample into consideration. Menhinick's index is number of species (S) divided by square-roots of the total number of individuals (n).

$$D = \frac{S}{\sqrt{n}} \quad \text{Equation 3.4}$$

Margalef's index is number of species (S) minus 1 divided by natural logarithm of the total number of individuals (n).

$$D = \frac{S - 1}{\ln(n)} \quad \text{Equation 3.5}$$

3.5.5 Species Evenness

Species evenness showed how close in number each species in an environment is. Buzas and Gibson's evenness is expressed by E^H/S where S is the number of species and H is Shannon entropy (Buzas & Gibson, 1969).

3.5.6 Shannon Diversity T-test

The differences in species diversity between distances (100 m, 500 m and 1000 m) was compared using Shannon diversity T-test. Shannon index here included a bias correction and may diverge slightly from the uncorrected estimate calculated elsewhere in PAST, at least for small sample. The estimator of the index is calculated by using p_i the proportion (0-1) of taxon, s number of taxa and N number of individuals as followed

$$H' = - \sum_{i=1}^s p_i \ln p_i - \frac{S-1}{2N} \quad \text{Equation 3.6}$$

The variance of the estimators is

$$\text{Var } H' = \frac{\sum p_i (\ln p_i)^2 - [\sum (p_i \ln p_i)]^2}{N} + \frac{S-1}{2N^2} \quad \text{Equation 3.7}$$

The t test statistic

$$t = \frac{H'_1 - H'_2}{\sqrt{\text{Var } H'_1 + \text{Var } H'_2}} \quad \text{Equation 3.8}$$

The degree of freedom for t test is

$$df = \frac{(VarH'_1 + VarH'_2)^2}{\frac{(VarH'_1)^2}{N_1} + \frac{(VarH'_2)^2}{N_2}} \quad \text{Equation 3.9}$$

3.5.7 Morista-Horn Index Test of Similarity

Similarity Morista-horn index was estimated by EstimateS software. Morista-horn index is influenced by species richness and sample size (Magurran, 2004). This index was chosen to avoid complex issue regarding the effect of sample size and density (Wolda, 1981). This index is widely used, for instances by Green (1999) who compared the similarity of spider population between two sampling method and two sampling time. Kalacska et al. (2004) measure beta diversity between three successional stages of a seasonally dry tropical forest using modified Morista-horn (Magurran, 2004).

3.5.8 Bipartite Graph

R software package bipartite was used to generate bipartite graphs to visualize the interaction and network between sites and species inhabiting the sites. The width of the web portray the abundances of the species inhabiting each site. The converged network between the species and site showed pattern of species inhabiting certain site.

3.5.9 Ivlev's Electivity Index

Ivlev's electivity index is used to characterize the degree of predator's selection towards particular prey species. This index is expressed as

$$E = \frac{r_i - p_i}{r_i + p_i} \quad \text{Equation 3.10}$$

where E is measure of electivity, r_i is relative abundance of prey item in the guts (proportion of total guts contents) and p_i is the relative abundance of the same prey item in the environment (Ivlev, 1961).

Relationships in the index are possible in a range -1 to +1, where negative showed avoidance, zero showed random selection and positive indicate active selection. Regurgitation sample and potential food resources of arthropod origin were identified in the lab using microscope based on Hill and Abang (2006). Relative abundance of regurgitation sample was used to represent r_i . Meanwhile, relative abundance of potential food resources during sampling represent p_i . This index assumed as unbiased and relatively independent of sample size (Strauss, 1979).

3.6.10 Linear Regression

Regression analysis is a statistical procedure that allow researchers to estimate the strength or magnitude of a relationship between two variables (Vik, 2014). This estimation can vary from nonexistence, weak to strong and to extend of almost perfect. Linear regression is a model to describe the relationship between a response y (dependent variable) and a set of predictor x (independent variables) (Cook & Weisberg, 1982). Correlation coefficient is a statistical tool to describe the degree of departure from perfect relationship and reveal the magnitude of association between two variables. Direction of correlation coefficient describes relationship where ($r > 0$) is a positive correlation, ($r < 0$) is a negative correlation, ($r = 0$) meaning no relationships and perfect relationship at $r = -1$ or $+1$ (Vik, 2014). Scatterplot was generated using R software in this study. Scatterplot tells us about the relationship between two variables where if the cluster of dots slope upward as we move along the x -axis, it shows positive relationship meanwhile if it slope downward as we move along the x -

axis the relationship is negative (Vik, 2014). R square and adjusted R square is generated through R software. R square is also known as coefficient of determination where it lies between 0% to 100% and higher R square value, better the model (Bhalla, 2018). R square (R^2) is calculated using SSE also known as sum of squared y values and SST which is the total sum of square y value (Westfall & Arias, 2019) as shown below.

$$R^2 = 1 - \frac{SSE}{SST} \quad \text{Equation 3.11}$$

Adjusted R square measures the proportion of variation explained by only those independent variables that really help in explaining the dependent variable (Bhalla, 2018). The difference between two is when you add an independent variable to a model, the R-squared increases, even if the independent variable is insignificant. It never declines. This explained by Westfall and Arias (2019) that with larger number of predictor variables, R square becomes increasingly biased upward. Meanwhile, adjusted R-squared increases only when independent variable is significant and affects dependent variable (James et al., 2014). Adjusted R square is calculated using

$$R^2_{adjusted} = 1 - \frac{(1 - R^2)(N - 1)}{N - p - 1} \quad \text{Equation 3.12}$$

where R^2 is sample R square, p is number of predictor and N total sample size (Bhalla, 2018).

In the study of relationship between number bulbul individuals with food resource in all three sites and Pelagus National Park, the variables that used in this study was the number of bulbul individuals as dependent variable and invertebrate in the environment and fruit weight as independent variables. The variable in this study wee logarithmically transformed

(log) to bring a highly skewed variable into one that is more approximately normal (Benoit, 2011).

Linear regression calculated using R-software generated R^2 , adjusted R^2 , f-statistic with p-value and coefficient table. Coefficient table have four components which is regression of beta coefficient and the t-statistic and p-value. The t-value for a given predictor is used to evaluate whether or not there is significant association between the predictor and the outcome variable that is whether the beta coefficient of the predictor is significantly different from zero.

CHAPTER 4

RESULT

4.1 Species Assemblage

Table 4.1 shows the number of bulbul species and individual from all sampling stations. The total sampling effort per site was 16 days. A total of 240 individuals comprising 12 species were captured in this study, equivalent to 44.4% of total bulbul species in Borneo. The dominant species caught in this study is the Spectacled bulbul with 46 individuals and followed by Puff-backed bulbul with 38 individuals. There are three near threatened species recorded in this study, which is Black and white bulbul, Grey-bellied bulbul and Puff-backed bulbul (IUCN 2016).

The station with the highest number of species and individuals is RJ2 with 10 species and 48 individuals. RL1 has the lowest number of species with 3 species while RJ3 has the lowest number of individuals with 9.

Table 4.1: A checklist of bulbul caught in mist nets at Pelagus National Park, Rumah John, Rumah Laja and Rumah Bujah

Species list	Pelagus National Park	Rumah John			Rumah Laja			Rumah Bujah			Total
		RJ 1	RJ 2	RJ 3	RL 1	RL 2	RL 3	RB 1	RB 2	RB 3	
<i>Microtarsus melanoleucos</i>											
(Black and white bulbul)	2	0	5	1	0	0	2	0	0	0	10
<i>Brachypodius atriceps</i>											
(Black-headed bulbul)	0	1	1	0	1	0	0	9	0	2	14
<i>Iole charlottae</i>											
(Buff-vented bulbul)	0	0	3	0	0	1	8	1	2	1	16
<i>Pycnonotus simplex</i>											
(Cream-vented bulbul)	0	1	4	0	0	0	3	2	0	1	11
<i>Pycnonotus cyaniventris</i>											
(Grey-bellied bulbul)	1	0	0	0	0	0	0	0	0	0	1
<i>Alophoixus bres</i>											
(Grey-cheeked bulbul)	5	0	2	5	2	3	1	2	3	3	26

Table 4.1 continued

<i>Tricholestes criniger</i>											
(Hairy-backed bulbul)	4	0	4	1	0	9	1	0	6	3	28
<i>Pycnonotus plumosus</i>											
(Olive-winged bulbul)	0	2	5	0	7	1	3	5	1	0	24
<i>Euptilotus eutilotus</i>											
(Puff-backed bulbul)	6	6	8	1	0	5	4	6	2	0	38
<i>Pycnonotus brunneus</i>											
(Red-eyed bulbul)	1	0	3	1	0	1	4	2	2	1	15
<i>Pycnonotus erythrophthalmos</i>											
(Spectacled bulbul)	2	0	13	0	0	5	20	2	0	4	46
<i>Alophoixus phaeocephalus</i>											
(Yellow-bellied bulbul)	5	0	0	0	0	0	0	1	2	3	11
Total number of individuals (from 4 visits)	26	10	48	9	10	25	47	30	18	18	
Total number of species	8	4	10	5	3	7	9	9	7	8	

4.1.1 Species Accumulation Curve by Sampling Stations

Figure 4.1 shows species accumulation curve of bulbul species caught using mist net at 10 stations in Pelagus. RB3 showed a steady ascending pattern, still climbing, not yet reaching asymptotes and maybe will continue to record new species if sampling effort continues. RJ2 has the highest species count in this graph with 10 species and reached asymptote at day 10. RJ1 and RL2 also reach asymptotes at day 10. RL3, RJ3 and RB2 reached plateau at day 12 with 9, 5 and 7 species respectively. RL1 reached asymptote early at day 5 with 3 species.

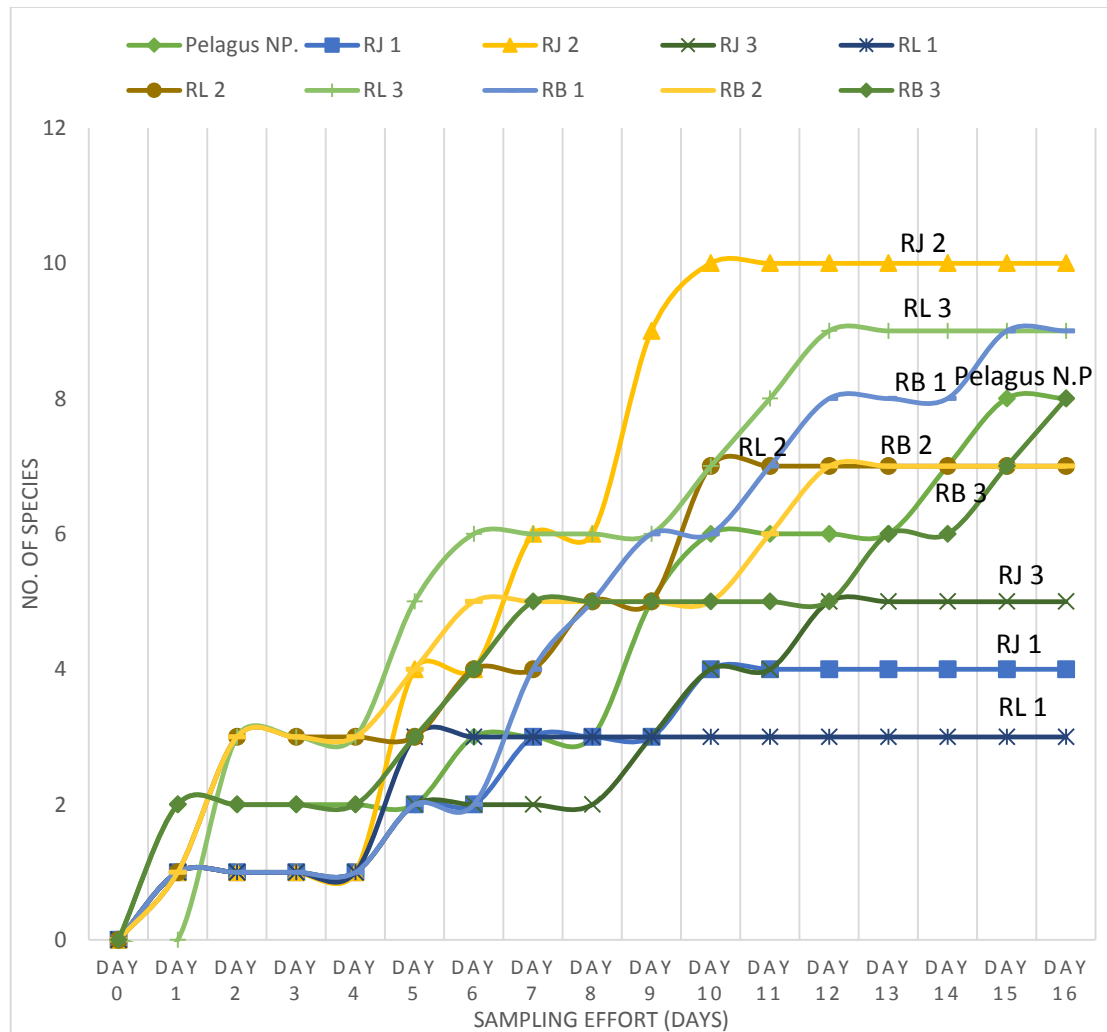


Figure 4.1: Species accumulation curve of bulbul species caught in 10 sampling stations at Pelagus, Kapit

4.1.2 Species Richness, Evenness and Diversity by Sampling Stations

In order to study bulbul community even further, rarefaction analysis was conducted by PAST software to estimate species richness.

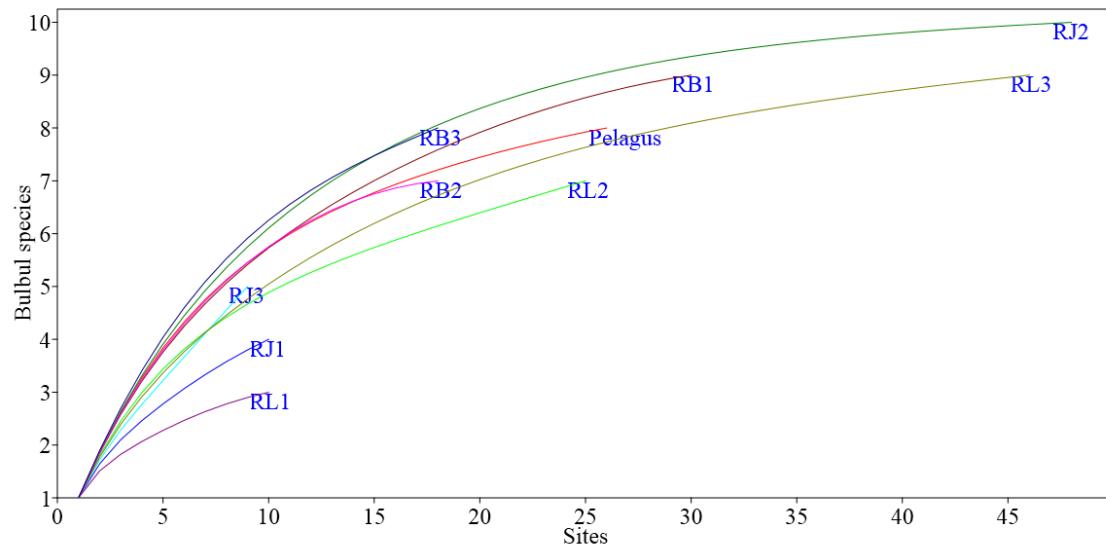


Figure 4.2: Rarefaction curve of bulbul in Pelagus

Stations RJ3, RJ1 and RL1 have less species compared to other sites while RJ2 has the most species. Pelagus National Park (PNP) have higher species than RL1, RJ1, RJ3, RL2, RB2 and RL3 (Figure 4.2).

Table 4.2: Estimated species richness index. Bold values indicate highest species richness

Location	PNP	RJ 1	RJ 2	RJ 3	RL 1	RL 2	RL 3	RB 1	RB 2	RB 3
Menhinick's richness index	1.569	1.265	1.443	1.667	0.949	1.400	1.327	1.643	1.65	1.886
Margalef's richness index	2.148	1.303	2.325	1.820	0.869	1.864	2.090	2.352	2.076	2.422

Table 4.2 shows the Menhinick's and Margalef's richness index for each sampling location. RB3 have the highest species richness according to Menhinick's and Margalef's richness index at 1.886 and 2.422 respectively. Lowest species richness index was reported for RL1 while Pelagus National Park, has Menhinick's richness index of 1.569 and Margalef's richness index of 2.148.

Species evenness among the bulbul community in this study was calculated using PAST Software. Based on Table 4.3, RB3 has the highest species evenness (0.884) while RL3 has the lowest (0.639), based on the data collected in this study.

Table 4.3: Species evenness for bulbul in Pelagus. Bold values shows highest species evenness

Location	PNP	RJ 1	RJ 2	RJ 3	RL 1	RL 2	RL 3	RB 1	RB 2	RB 3
Evenness	0.841	0.743	0.815	0.736	0.743	0.746	0.639	0.766	0.866	0.884

Table 4.4: Species diversity indices for bulbul at all sampling station in Pelagus. Bold values indicate highest species diversity

Location	PNP	RJ 1	RJ 2	RJ 3	RL 1	RL 2	RL 3	RB 1	RB 2	RB 3
Simpson index	0.834	0.580	0.853	0.642	0.460	0.771	0.754	0.822	0.809	0.846
Shannon index	1.906	1.089	2.097	1.303	0.802	1.652	1.750	1.931	1.802	1.956

Table 4.4 shows species diversity for all sampling stations in this study. The highest species diversity indices according is recorded for RJ2 (Simpson index: 0.853, Shanon Index: 2.097) followed by RB 3 (Simpson index: 0.846, Shanon index: 1.956). Meanwhile the lowest species diversity is at RL1 (Simpson index: 0.460, Shanon index: 0.802).

4.1.3 Species Similarity by Sampling Stations

Similarity and shared species of bulbul in Pelagus is calculated using Morista-Horn index in Estimate-S software to observe the similarity among all stations in Pelagus. Using scale 0 to 1 to indicate the similarity, 0 to 0.24 indicate little similarity, 0.25 to 0.49 is lower similarity, 0.5 to 0.75 is high similarity, 0.75 to 0.99 is very similar and 1 is completely similar. From Table 4.5 the highest similarity is between RL3 and RJ2 with index of 0.856 (very similar) with nine shared species. Lowest similarity is 0.058 with two shared species, represent by RB3 and RJ1.

Stations at similar distances from longhouses were compared to see the similarity of bulbul communities. There are few sites that have high similarity, these were between stations RL2 versus RJ2 (0.701), RB1 versus RJ1 (0.636) and RB3 versus RL3 (0.61). Stations of RB2 versus RL2 (0.825) showed very similar bulbul composition between them. Meanwhile, other stations at similar distances showed little to lower similarity.

The bipartite graph (Figure 4.3) shows the sampling stations and what species are found there. The thickest web shows that most of SB was recorded at RB3 while the thinnest web connects with PNP. There are three near-threatened species recorded in this study, which is Black and white bulbul, Grey-bellied bulbul and Puff-backed bulbul based on IUCN (2016). Grey-bellied bulbul can only be found in PNP. Black and white bulbul can be found in PNP, RJ2, RJ3 and RL3. Puff-backed bulbul can be found in most stations except in RL1 and RB3. Grey-checked bulbul can be found almost in all sampling stations except in RJ1.

Table 4.5: Morisita-horn indices used to show similarity and shared species of bulbul community in all sites in Pelagus. Number of shared species is in parentheses. Bold value indicate highest similarity. * indicate lowest similarity

	PNP	RJ 1	RJ 2	RJ 3	RL 1	RL 2	RL 3	RB 1	RB 2	RB 3
PNP		0.473 (1)	0.580 (6)	0.620 (5)	0.109 (1)	0.718 (5)	0.329 (6)	0.426 (5)	0.754 (5)	0.681 (5)
RJ1			0.463 (4)	0.171 (1)	0.313 (2)	0.395 (2)	0.216 (3)	0.636 (4)	0.254 (2)	0.058* (2)
RJ2				0.275 (5)	0.243 (3)	0.701 (7)	0.856 (9)	0.552 (8)	0.431 (6)	0.631 (7)
RJ3					0.247 (1)	0.454 (4)	0.128 (5)	0.249 (3)	0.562 (4)	0.458 (3)
RL1						0.135 (2)	0.127 (2)	0.446 (3)	0.198 (2)	0.128 (2)
RL2							0.539 (7)	0.354 (6)	0.825 (6)	0.673 (5)
RL3								0.352 (7)	0.243 (6)	0.61 (6)
RB1									0.311 (6)	0.446 (7)
RB2										0.661 (5)
RB3										-

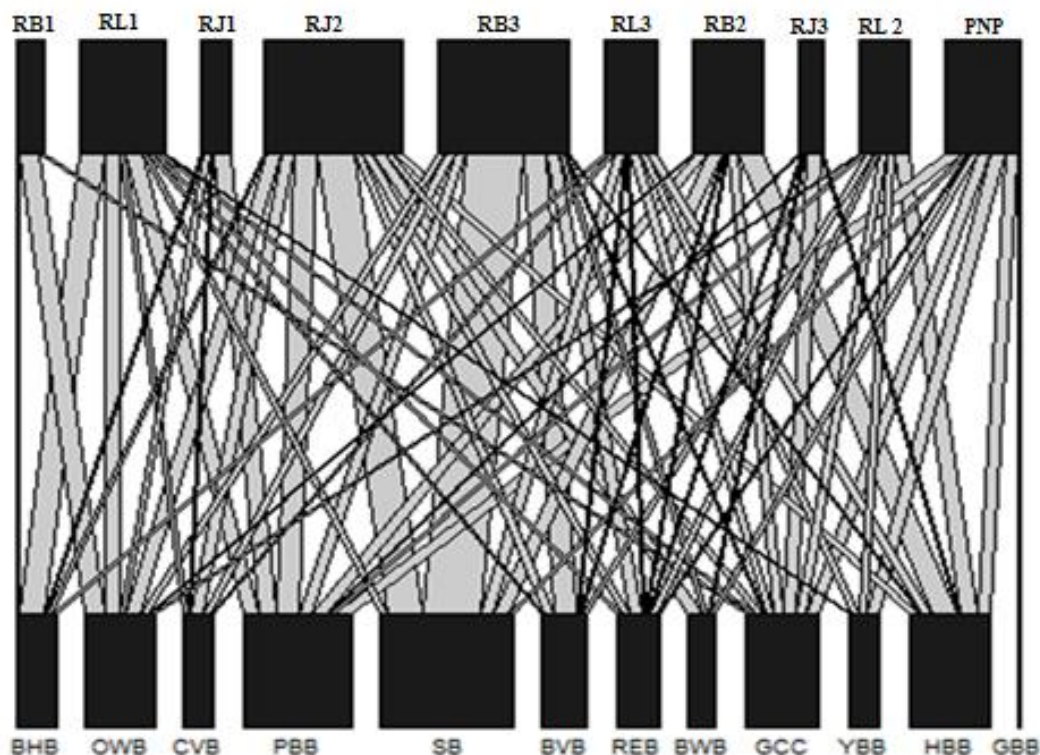


Figure 4.3: Bipartate graph of bulbul species in Pelagus. The top axis shows the sampling stations and the lower axis shows the species name. The species names are: BHB: Black-headed bulbul, OWB: Olive-winged bulbul, CVB: Cream-vented bulbul, PBB: Puff-backed bulbul, SB: Spectacled bulbul, BVB is Buff-vented bulbul, REB is Red-eye bulbul, BWB is Black and white bulbul, GCC: Grey-checked bulbul, YBB: Yellow-bellied bulbul, HBB: Hairy-backed bulbul and GBB: Grey-bellied bulbul

4.1.4 Effect of Distances from Longhouse on Bulbul Community

The anthropogenic effect originating from the longhouse community is expected to produce some effect on wildlife. In this study bulbul was used as a model animal to measure the effect.

Table 4.6 shows the total number of birds captured throughout the study at 100 m, 500 m and 1000 m from three longhouses, namely Rumah John, Rumah Laja and Rumah Bujah. Among all the distances, 500 m has the highest number of individuals and species, which is 91 and 11 respectively. Hairy-backed bulbul has the highest species count in 500 m site with 19 individuals. The site of 1000 m have 73 number of individuals with 11 species. Spectacled

bulbul is the dominant species at the 1000 m station. Site of 100 m have 50 individuals and nine species and have Olive-winged Bulbul as dominant species at 100 m from the longhouses with 14 individuals.

Table 4.6: Number of bulbul species captured at 100 m, 500 m and 1000 m from longhouses. Bold indicate most abundant species

Species list	100 m	500 m	1000 m
<i>Alphoixus bres</i> (Grey-cheeked bulbul)	4	8	9
<i>Alphoixus phaeocephalus</i> (Yellow-bellied bulbul)	1	2	3
<i>Brachypodius atriceps</i> (Black-headed bulbul)	11	1	2
<i>Euptilotus eutilotus</i> (Puff-backed bulbul)	12	15	5
<i>Iole charlottae</i> (Buff-vented bulbul)	1	6	9
<i>Microtarsus melanoleucos</i> (Black and white bulbul)	0	5	3
<i>Pycnonotus simplex</i> (Cream-vented bulbul)	3	4	4
<i>Pycnonotus plumosus</i> (Olive-winged bulbul)	14	7	3
<i>Pycnonotus brunneus</i> (Red-eyed bulbul)	2	6	6
<i>Pycnonotus erythroptalmos</i> (Spectacled bulbul)	2	18	24
<i>Tricholestes criniger</i> (Hairy-backed bulbul)	0	19	5
No. of individuals	50	91	73
No. of species	9	11	11

Rarefaction curve was calculated using PAST software to observe the species richness between 100 m, 500 m and 1000 m. Based on Figure 4.4, 500 m has the highest species. Sites 1000 m and 500 m has reached its asymptotes. Site 100 m still climbing but steady.

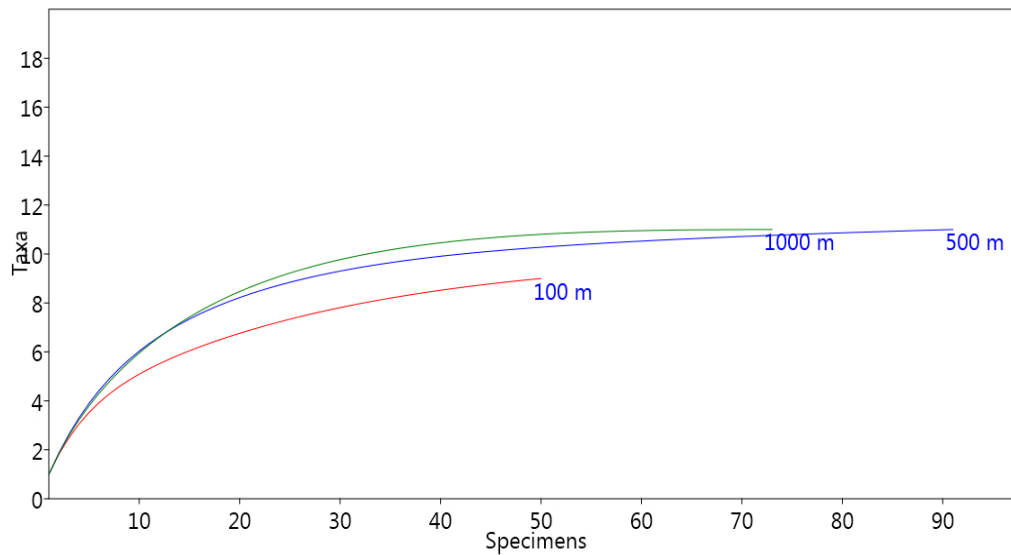


Figure 4.4: Rarefaction of distances from three longhouses combine

Table 4.7: Species richness index and evenness for 100 m, 500 m, and 1000 m site from longhouses. Symbol * showed the highest species richness between 100 m, 500 m, and 1000 m. Bold value showed highest species evenness

	100 m	500 m	1000 m
Menhinick's index	1.273	1.153	1.287*
Margalef's index	2.045	2.217	2.331*
Chao 1	9.333	11*	11*
Evenness	0.684	0.777	0.747

Species richness indices showed that the 1000 m site has the highest species richness index among all the disturbed sites with Menhinick's richness index of 1.287 and Margalef's

richness index of 2.331 (Table 4.7). Highest Chao 1 is represented by both 500 m and 1000 m with 11. Location with lowest Margalef's richness index of 2.045 is 100 m while location with lowest Menhinick's richness index of 1.153 is 500 m. Table 4.7 also showed that among all the disturbed sites, 500 m has the highest species evenness of 0.777.

4.1.5 Species Diversity by Distance from Longhouse and Pelagus National Park

Species diversity for 100 m, 500 m, 1000 m and control site Pelagus National Park is given in Table 4.8. Distances 500 m from longhouses show the highest diversity index which is 0.863 and 2.145 from both Simpson and Shannon index. Lowest diversity index is shown by 100 m with 0.802 and 1.817, Simpson and Shannon index respectively. Control site showed a Simpson index and Shannon index with 0.834 and 1.906 respectively.

Table 4.8: Species diversity for different distances from longhouses and PNP. Bold showed highest species diversity

	100 m	500 m	1000 m	PNP
Simpson index	0.802	0.862	0.837	0.834
Shannon index	1.817	2.145	2.106	1.906

Zar T-test was conducted on Shannon Indices for all the distances (100 m, 500 m, 1000 m) to test whether any differences between a pair of indices were significant or not. The Null hypothesis is no significant difference between any two sites. T-test between 1000 m and 500 m; PNP and 100 m; PNP and 500 m; PNP and 1000 m; 500 m and 1000 m showed P-value more than 0.05 so it failed to reject null hypothesis. There is not enough evidence that would suggest acceptance of alternative hypothesis, so null hypothesis accepted. T-test of 100 m and 500 m showed P-value less than 0.05 so null hypothesis is rejected, there is

enough evidence that would suggest alternative hypothesis that there is a difference between 100 m and 500 m.

Table 4.9: P-value for Shannon diversity T-test generated by PAST software (Version 3.22) between 100 m, 500 m and 1000 m. * indicate significant difference ($p < 0.05$)

	PNP	100 m	500 m	1000 m
PNP		0.60	0.11	0.21
100 m			0.02*	0.06
500 m				0.75
1000 m				

Analysis of similarity between all distances (100 m, 500 m and 1000 m) and control sites was conducted using Estimate-S to see similarity among them. Highest similarity and shared species are between 1000 m and 500 m with Morista-Horn index of 0.823 and 11 species (Table 4.10) and lowest between 1000 m and 100 m (Morisita-Horn index of 0.369) despite sharing quite high number of species (9).

Table 4.10: Morisita-Horn indices of similarity and number of shared species (in bracket) between Pelagus National Park (PNP), 100 m, 500 m and 1000 m. Bold value indicate highest similarity

	PNP	100 m	500 m	1000 m
PNP	-	0.435 (5)	0.746 (7)	0.544 (7)
100 m		-	0.508 (9)	0.369 (9)
500 m			-	0.823 (11)
1000 m				-

Based on all the analysis presented above, the 100 m site have the lowest number of individuals, number of species, species diversity, species richness and species evenness compared to other two distances while the 500 m site have the highest number of individuals, species diversity, species richness and species evenness. Zar T-test showed sites 500 m and 1000 m to have no significant difference in Shannon index. Morista-horn index also indicated high similarity between 500 m and 1000 m sites. The control site Pelagus National Park have a high species diversity (0.8343) and evenness (0.8405) while having highest similarity with 500 m compared to with 100 m and 1000 m.

4.2 Food Resources in Pelagus

4.2.1 Fruits

The fruit data was based on one-year collection using 1x1 m² fruit nets that were deployed at 100, 500 and 1000 m from the longhouses and in Pelagus National Park. Fruits that dropped into the net were collected, identified, labeled, weighted and recorded. Plant species checklist represented in the fruit sample is given in Table 4.11.

Table 4.11: Plant species list and fruit weight collected from Pelagus National Park (PNP), Rumah John, Rumah Laja and Rumah Bujah.
 *Durio sp found at Rumah John at 100 m but not weighted. In unknown sample, in bracket showed how many samples of unknown sample of fruits

Family name	Species list/Site	PNP	Rumah John			Rumah Laja			Rumah Bujah			Total weight (g)	Percentage (%)
			RJ 1	RJ 2	RJ 3	RL 1	RJ 2	RL 3	RB 1	RB 2	RB 3		
Actinidiaceae	Saurauia sp	-	-	-	-	-	-	3.18	3.22	1.19	0.65	8.24	0.55
Actinidiaceae	Leea sp	-	-	-	-	-	6.06	2.83	-	-	-	8.89	0.59
Ampelidaceae	Campnosperma sp	-	-	-	-	-	-	-	0.16	-	-	0.16	0.01
Ampelidaceae	<i>Dracontomelum dao</i>	-	4.6	-	-	-	-	-	-	-	-	4.6	0.31
Aquifoliaceae	<i>Ilex cissoidea</i>	-	-	-	-	-	-	-	0.45	-	0.117	0.57	0.04
Arecaceae	Arenga sp.	-	-	4.63	-	-	-	-	-	-	-	4.63	0.31
Bombacaceae	Durio sp.	-	*	-	-	-	-	-	-	-	-	0	0.00
Calamoideae	Calamus sp	-	-	-	-	-	-	-	1.4	1.77	1.94	5.11	0.34
Crypteroniaceae	<i>Crypteronia griffithii</i>	-	-	-	-	-	-	-	2.12	0.74	1.07	3.93	0.26
Dilleniaceae	<i>Dillenia suffruticosa</i>	-	-	-	-	-	-	-	3.39	4.6	3.15	11.14	0.74
Elaeocarpaceae	Elaeocarpus sp	16.79	-	6.84	5.1127	-	-	-	5.7	0.04	-	34.48	2.30
Euphorbiaceae	Baccaurea sp	26.05	-	-	-	-	-	-	5.85	4.52	0.05	36.47	2.44
Euphorbiaceae	<i>Hevea brasiliensis</i>	-	8.31	-	-	15.92	3.3	-	-	-	-	27.53	1.84

Table 4.11 continued

Euphorbiaceae	<i>Macaranga costula</i>	-	-	-	-	14.07	75.07	-	-	-	-	89.14	5.96
Euphorbiaceae	<i>Macaranga</i> sp	25.21	2.03	-	-	-	-	-	1.12	7.01	0.57	35.94	2.40
Euphorbiaceae	<i>Mallotus wrayi</i>	-	-	-	-	-	-	-	1.34	3.99	1	6.33	0.42
Fabaceae	<i>Spatholobus</i> sp	-	-	-	-	-	-	-	-	-	0.37	0.37	0.02
Fabaceae	<i>Lithocarpus</i> sp	-	-	-	-	7.87	-	-	-	-	-	7.87	0.53
Juglandaceae	<i>Engelhardtia</i> sp	-	1.68	-	-	-	-	-	-	-	-	1.68	0.11
Lauraceae	<i>Litsea</i> sp	-	-	-	-	-	-	3.55	5.17	3.41	1.01	13.14	0.88
Lumiaceae	<i>Callicarpa</i> sp	-	-	-	-	-	-	-	0.3	0.26	0.32	0.88	0.06
Lumiaceae	<i>Vites pubescens</i>	-	-	-	-	-	-	-	-	2.41	0.79	3.20	0.21
Lumiaceae	<i>Vitex flava</i>	-	-	-	-	-	-	-	1.93	4.82	3.63	10.38	0.69
Melastomataceae	<i>Creaghiella pupurea</i>	-	-	0.93	-	-	-	-	-	-	-	0.93	0.06
Melastomataceae	<i>Melastoma malabathricum</i>	-	-	-	-	-	-	11.5	-	-	-	11.50	0.77
Melastomataceae	<i>Pternandra</i> sp	-	-	-	-	-	529.94	51.29	2.51	1.98	0.28	586.0	39.16
Meliaceae	<i>Dysoxylum magnificum</i>	-	-	-	-	-	8.79	2.17	-	-	-	10.96	0.73
Moraceae	<i>Artocarpus</i> sp	-	-	-	-	-	2.25	-	-	-	-	2.25	0.15
Moraceae	<i>Ficus</i> sp	-	-	-	-	-	-	-	15	7.7	6.96	29.66	1.98
Moraceae	<i>Ficus grossularioides</i>	-	-	-	-	0.07	-	-	18.87	18.36	9.55	46.85	3.13

Table 4.11 continued

Myristicaceae	Horsfieldia sp	-	0.54	-	-	0.54	-	-	-	-	-	1.08	0.07
Myrtaceae	<i>Syzygium polyanthum</i>	-	-	-	-	-	-	-	1.89	1.01	2.67	5.57	0.37
Myrtaceae	Syzygium sp	-	-	-	6.13	1.063	-	10.8	3.18	3.85	3.77	28.79	1.92
Phyllanthaceae	Glochidion sp	-	-	-	-	-	-	-	3.3	4.96	4.432	12.69	0.85
Rubiaceae	Timonius sp	-	-	-	-	-	-	-	13.17	4.18	10.89	28.24	1.89
Symplocaceae	<i>Symplocos pendula</i>	-	-	-	-	-	-	-	0.66	0.51		1.17	0.08
Tiliaceae	Brownlowia sp	-	-	-	-	-	-	-	0.91	0.41	2.33	3.65	0.24
-	Unknown (g, number of unknown samples in bracket)	42.03 (6)	0.81 (1)	15.36 (7)	21.12 (6)	5.00 (3)	42.8 (18)	148.3 0 (21)	41.62 (28)	81.42 (26)	13.89 (25)	412.35	27.56
	Total	110.1	17.97	27.76	32.36	44.53	668.2	233.6	133.26	159.14	69.44	1496.4	100%

A total of 494 fruit samples weighing 1496.4 g was collected from all longhouses and Pelagus National Park over the period of one year. Twenty-four families of plant were identified from the fruit samples collected in this study.

In Pelagus National Park two families were recorded which is Elaeocarpaceae and Euphorbiaceae. The rest of the sample is unknown. At Rumah John's stations 9 families of plants were represented, which were Anacardiaceae, Arecaceae, Bombacaceae, Elaeocarpaceae, Euphorbiaceae, Juglandaceae, Melastomaceae, Myristicaceae, Myrtaceae and the rest unknown. In Rumah Laja's station, nine families were collected, these were Actinidiaceae, Ampelidaceae, Euphorbiaceae, Fagaceae, Lauraceae, Melastomataceae, Meliaceae, Moraceae, Myristicaceae and Myrtaceae. In Rumah Bujah's stations, 18 families can be identified, and the rest is unknown sample of fruit. Those 18 families were Actinidiaceae, Anacardiaceae, Aquifoliaceae, Calamoideae, Crypteroniaceae, Dilleniaceae, Elaeocarpaceae, Euphorbiaceae, Fabaceae, Lauraceae, Lumiceae, Melastomataceae, Moraceae, Myrtaceae, Phyllanthaceae, Rubiaceae, Symplocaceae, Tiliceae and there were also unidentified families.

The most dry fruits weight were collected at Rumah Laja 500 m station with 668.21 g while the lowest was collected at RJ1 station with 17.97 g. Dry fruit weight collection in all three stations was lowest for Rumah John (78.10 g) and highest for Rumah Laja (946.36 g). At the single sampling station in PNP 110.08 g of dry fruit weight was collected. The 500 m stations at Rumah Laja and Rumah Bujah recorded the highest fruit collection for their respective site with dry weights of 668.21 g and 159.14 g, respectively. Meanwhile for Rumah John, the station with the most dry fruit collection was RJ3 (1000 m) with 32.36 g. *Pternandra* sp. was the most

collected species in this study with 39.16% out of all species. *Pternandra* sp. was collected mostly at RJ2 with 529.54 g. The was followed by *Macaranga costula* with 5.95 g and third is *Ficus grossularioides* with 3.13 g. *Macaranga costula* was the highest collection at RJ2 with 75.07 g while *Ficus grossularioides* was collected mostly at RB1 with 18.87 g.

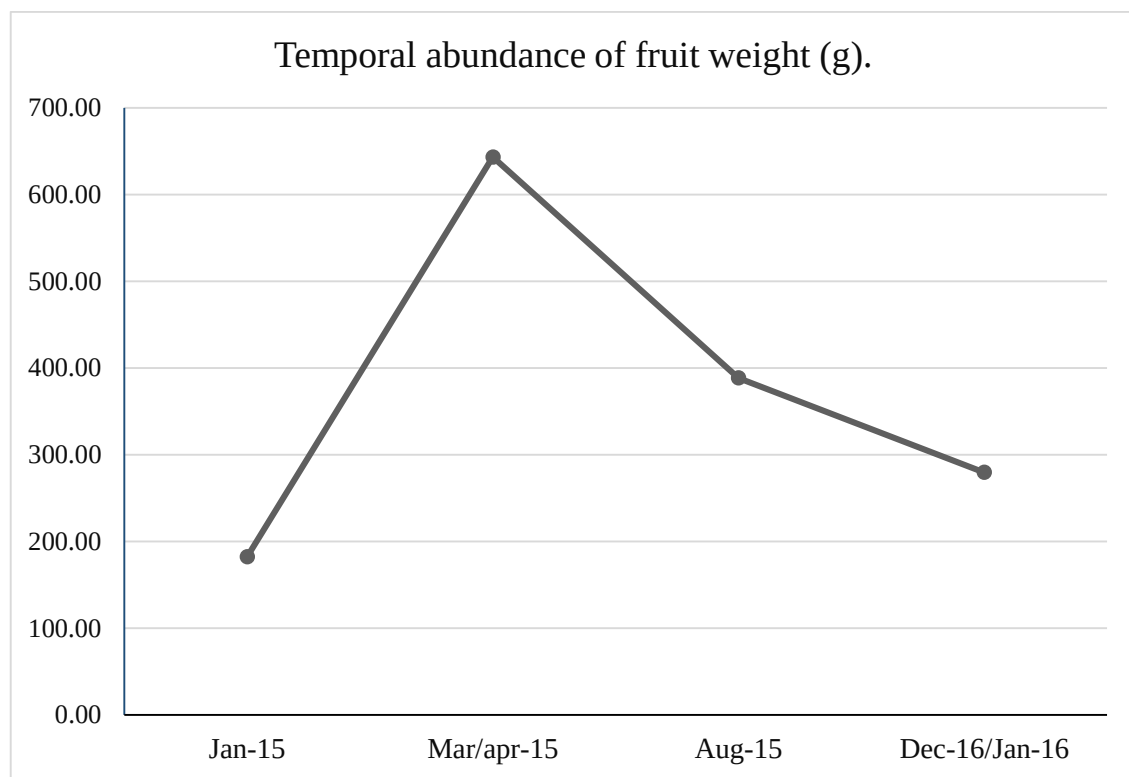


Figure 4.5: Temporal pattern of fruit weight

Figure 4.5 shows the timeline of fruit weight overall in all site combined. Based on Figure 4.5, the lowest dry fruit collection was in January 2015, after which collection increased dramatically in March/April 2015. There after the collection decreased by about 40% in August 2015 and by a further 16% in December 2015/January 2016.

4.2.2 Invertebrates

Invertebrates are potential food sources for bulbuls. Based on Table 4.12 the total number of invertebrate collected was 20,037. This collection included four classes of invertebrate, which are arachnida, chilopoda, gastropoda and insecta. Class Insecta was represented by 13 orders during this sampling. Diptera was the most abundant order in this study with total of 11,295 individuals comprising of 56% of the total arthropods collected (Figure 4.6). Next was hymenoptera with 5,952 individuals which make up 30% of total arthropod collected (Figure 4.6). The lowest insect order collected was Phasmida with 1 individual.

Comparison among stations showed Rumah Laja 500 m has the most individuals (3,973 individuals), followed by Rumah John 100 m with 2,734 individuals and Rumah Laja 100 m with 2,463 individuals. The single station in PNP has the lowest invertebrate count with 1042 individuals. Overall invertebrate count from Rumah John's site was 6,067 individuals, Rumah Laja 8,715 individuals and Rumah Bujah 4,213 individuals.

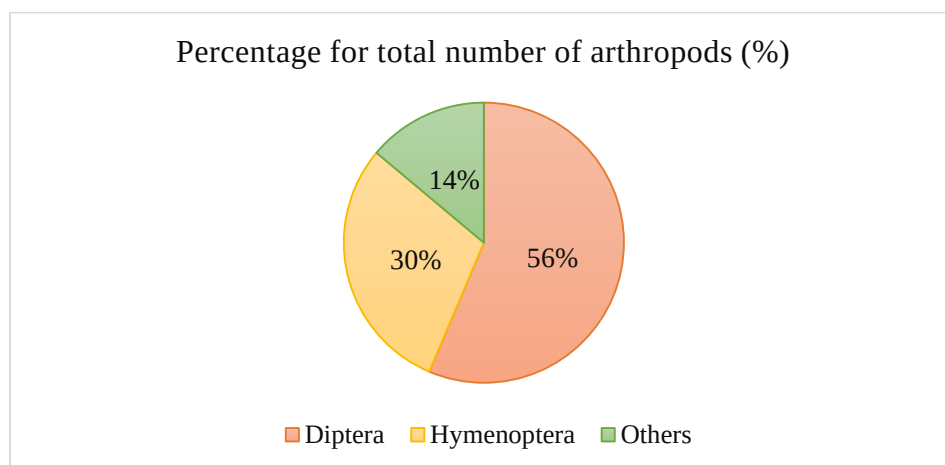


Figure 4.6: Percentage of total number of arthropods

Table 4.12: List of invertebrate orders in all longhouses and Pelagus National Park

Class name	Order name	Rumah John			Rumah Bujah			Rumah Laja			PNP	Total no. of arthropods	Percentage (%)
		100 m	500 m	1000 m	100 m	500 m	1000 m	100 m	500 m	1000 m			
Arachnida	-	15	24	16	26	27	27	15	22	29	10	211	1.05
Chilopoda	-	1	3	1	3	8	4	7	5	7	10	49	0.24
Gastropoda	-	0	1	0	0	0	0	1	0	0	0	2	0.01
Insecta	Coleoptera	99	196	132	155	142	173	122	130	189	170	1508	7.53
Insecta	Dermaptera	2	3	1	0	3	1	2	3	2	0	17	0.08
Insecta	Dictyoptera	27	20	22	18	12	15	31	8	12	9	174	0.87
Insecta	Diptera	1212	736	1271	803	1186	739	1179	3015	825	329	11295	56.37
Insecta	Ephemenoptera	34	74	51	11	23	24	21	31	34	32	335	1.67
Insecta	Hemiptera	6	10	13	9	6	20	4	17	3	7	95	0.47
Insecta	Hymenoptera	1293	423	261	249	211	215	1053	659	1142	446	5952	29.71
Insecta	Isoptera	10	13	8	6	2	36	17	73	6	10	181	0.90

Table 4.12 continued

Insecta	Lepidoptera	22	7	24	13	5	9	7	2	14	6	109	0.54
Insecta	Odonata	0	1	0	0	0	0	0	0	0	0	1	0.005
Insecta	Orthoptera	13	8	14	12	10	10	4	7	16	11	105	0.52
Insecta	Phasmatodea	0	0	0	0	0	0	0	1	0	0	1	0.005
Insecta	Siphonaptera	0	0	0	0	0	0	0	0	0	2	2	0.01
Total individuals		2,734	1,519	1,814	1,305	1,635	1,273	2,463	3,973	2,279	1,042	20,037	

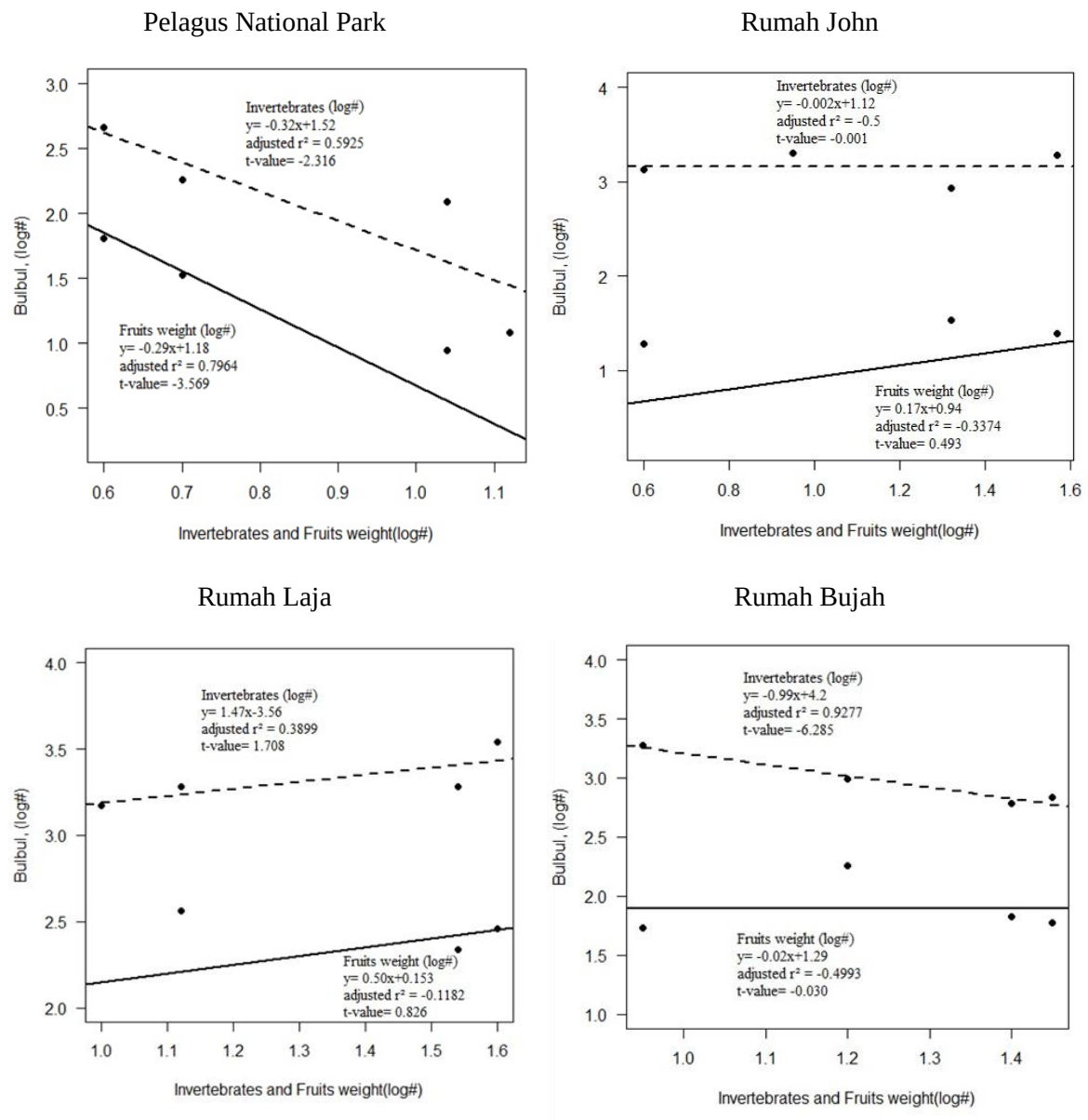


Figure 4.7: Relationship between food resource and bulbul abundance in all longhouse and Pelagus National Park. Dash line represent invertebrate and straight line represents fruit weight. Bulbul (log) on Y-axis and invertebrate and fruit weight on X-axis. Bulbul (log) represent bulbul abundance

4.2.3 Relationship between Bulbul and Food Resource Based on Sites

Figure 4.7 shows the relationship between bulbul abundance and its potential food resources, which are invertebrates and fruits. For Pelagus National Park there is negative relationships between bulbuls and invertebrate and fruit weight. Rumah John showed two different relationships, positive for fruit weight but negative for invertebrate. In Rumah Laja, bulbul abundance has a positive relationship with both invertebrate and fruit weight. Only at Rumah Bujah is bulbul abundance strongly correlated ($r^2 = 0.928$) in a negative way with the number of invertebrates in the environment. The different responses suggest that other environmental factors than food resources may influence bulbul abundance. The t-values in Figure 4.7 are all generally low (no significant relationship between bulbuls and food resources) except for the relationship between bulbuls at Rumah Bujah and invertebrates in the environment ($t = -6.285$).

4.2.4 Temporal Pattern of Bulbul and Food Abundance and Its Relationship

Figure 4.8 shows the temporal pattern of number of invertebrates, fruit weight and number of bulbuls. This temporal pattern is generated to see whether the pattern of bulbul numbers follow that of their potential food resources. The duration of this study is from December 2014 to December 2015.

Bulbul abundance ascended steadily from December 2014 to August 2015, then decreased from August 2015 to November 2015. Fruit weight have an up and down pattern that can be observed in the line graph, peaking in March-April 2015. In contrast, invertebrate pattern is almost steady throughout the year. From this graph we can see bulbul and fruit weight decrease at the end of the year, suggesting there may be an overall relationship between them.

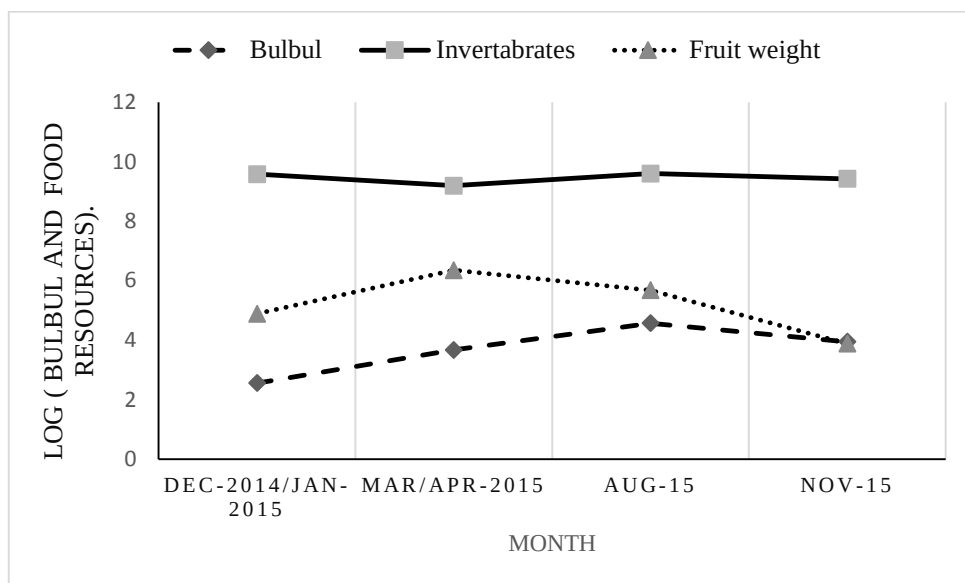


Figure 4.8: Temporal pattern of bulbul and food abundance against sampling period in course of one year

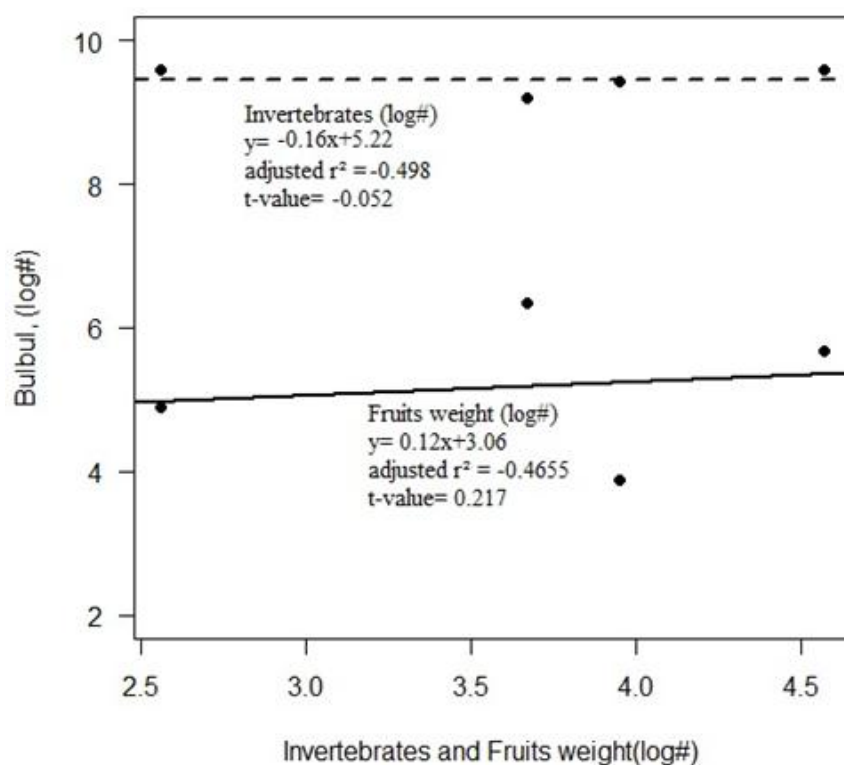


Figure 4.9: Relationship of bulbul abundance against invertebrate and fruit weight over period of one year. Dash line with point represent invertebrate and straight line represent fruit weight

Fruit weight show a weak positive relationship with bulbul abundance based on regression graph (Figure 4.9) but this relationship is not significant. Meanwhile, there is no relationship (t-value = -0.052) between invertebrate and bulbul abundance. This may due to a relatively stable collection of invertebrate in course of the year (Figure 4.9). Based on this Figure 4.8 and Figure 4.9 only fruit weight showed a slightly positive relationship with bulbul abundance during the duration of one year.

4.3 Diet of Bulbul

A total of 240 individuals from 12 species of bulbuls were caught for this study. From these, 111 diet samples were collected via the method of regurgitation, stomach content and fecal extraction. There were 79 samples of regurgitation, 3 samples of stomach content and 29 samples of faecal extraction (Table 4.13). Sixty-six samples (59%) contained plant only, 23 samples (21%) contained insect only and 22 samples (20%) contained a mixture of plant and insect (Figure 4.10). Plant materials were present in a total of 88 samples while insects were present in a total of 45 samples. Since the plant materials in the diet lacked fiber they are most likely to be fruit.

Table 4.13: Diet of bulbuls based on samples collection method

Categories	Total samples	Insect only	Plant only	Insect + plant
Regurgitation	79	16	45	18
Stomach content	3	1	1	1
Faecal extraction	29	6	20	3
Total	111	23	66	22

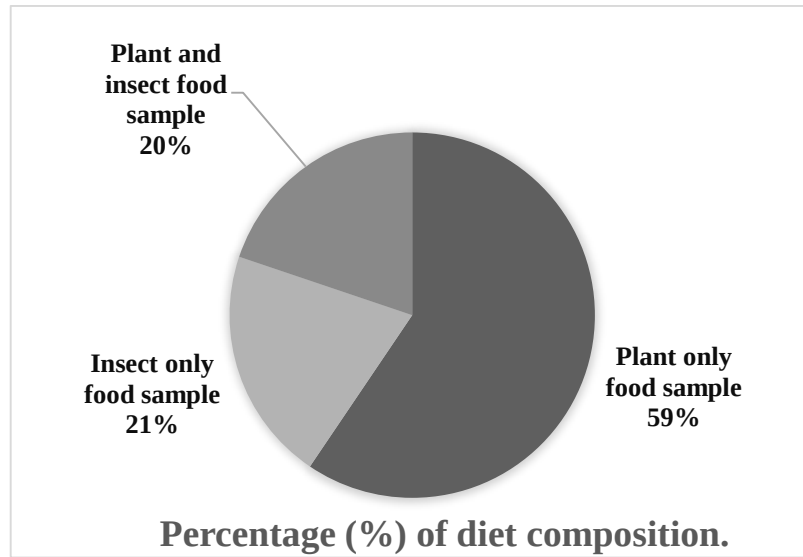


Figure 4.10: Major categories of bulbul diets in Pelagus

4.3.1 Invertebrates in Bulbul Diet

Identified insect parts are grouped into their respective orders. Out of 45 diet samples that contained insect, 21 samples (46.6%) contained fragments which allowed identification to order level. Insect fragments from 24 samples (53.3%) cannot be identified, even to order level, because the components were crushed and masticated beyond identification.

Seven orders of insects were detected in 21 diet samples from eight species of bulbul (Figure 4.11). Coleoptera (43%) was the most commonly consumed insect order followed by Hymenoptera (19%) and Diptera (14%). Bulbul in this study also consumed Orthoptera, Isoptera, Hemiptera and Dictyotera.

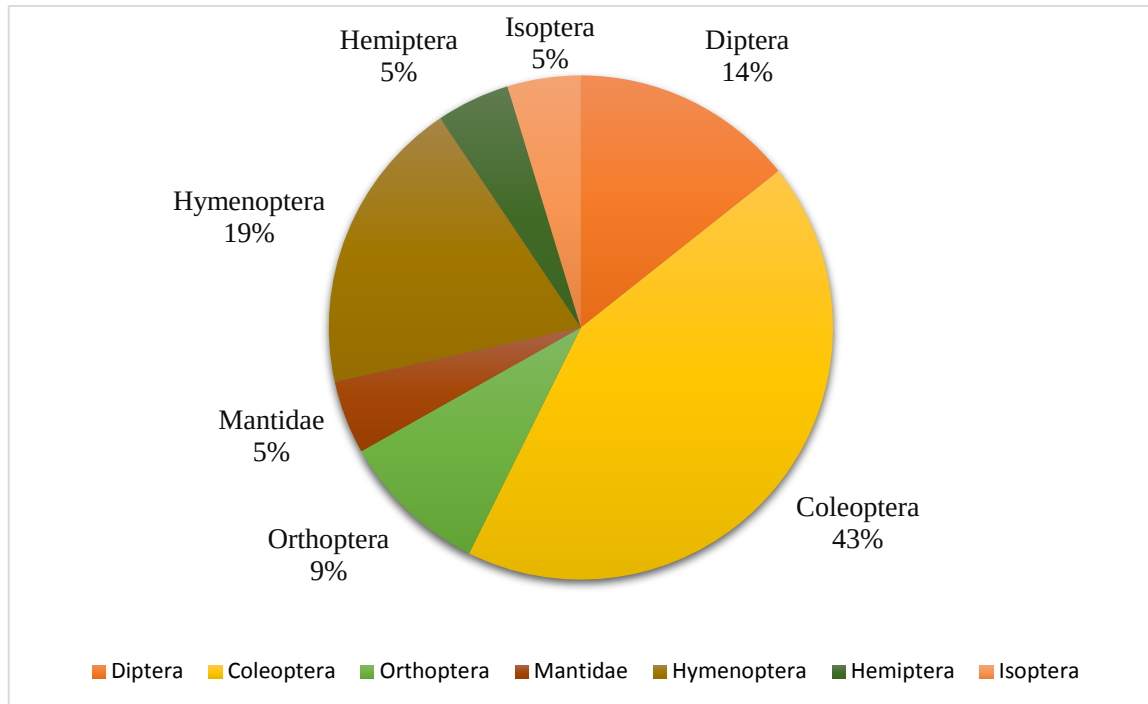


Figure 4.11: Percentage of insects orders that can be found in bulbul diet

Diptera was found only in three diet samples from Hairy-backed bulbul (Table 4.14). Coleoptera were found in nine samples and inside six bulbul species which are Black-headed bulbul, Hairy-backed bulbul, Olive-winged bulbul, Puff-backed bulbul, Spectacled bulbul and Yellow-bellied bulbul. Mantidae, Hemiptera and Isoptera were found only once in bulbul diet sample.

Table 4.14: List of bulbul species and the insect found in their diet

	Diptera	Coleoptera	Orthoptera	Mantidae	Hymenoptera	Hemiptera	Isoptera
Black-headed bulbul	0	1	0	0	0	0	0
Buff-vented bulbul	0	0	0	0	1	0	0
Grey-cheeked bulbul	0	0	0	1	1	0	1
Hairy-backed bulbul	3	2	0	0	0	1	0
Olive-winged bulbul	0	3	0	0	0	0	0
Puff-backed bulbul	0	1	0	0	0	0	0
Spectacled bulbul	0	1	2	0	2	0	0
Yellow-bellied bulbul	0	1	0	0	0	0	0
Total Insect in diet	3	9	2	1	4	1	1
Percentage in diet (%)	14.3	42.9	9.5	4.7	19	4.7	4.7

Table 4.15: Ivlev electivity index. Bold value indicate highest measure of electivity, E

No.	Order of insect	Relative abundance of prey item in food sample, r_i	Relative abundance if the same prey item in the environment, p_t	Measure of electivity, E
1	Diptera	14.3	56.3	-0.59
2	Coleoptera	42.9	9.5	+0.64
3	Orthoptera	9.5	0.5	+0.90
4	Dictyoptera	4.8	0.9	+0.68
5	Hymenoptera	19	29.7	-0.22
6	Hemiptera	4.8	0.5	+0.81
7	Isoptera	4.8	0.9	+0.68
8	Arachnidae	0	1.05	-1
9	Chilopoda	0	0.24	-1
10	Dermaptera	0	0.08	-1
11	Ephemeroptera	0	1.67	-1
12	Gastropoda	0	0.01	-1
13	Lepidoptera	0	0.48	-1
14	Odonata	0	0.00	-1
15	Phasmida	0	0.00	-1
16	Siphonaptera	0	0.01	-1

Ivlev's electivity index is used to measure the degree of selection of a particular prey by the predator. Table 4.15 shows Orthoptera having the highest ivlev electivity index with $E = +0.9$ and together with Hemiptera ($E = +0.81$), these are two preferred prey of bulbul. There are several other orders that are selected by bulbul, which include Coleoptera ($E = +0.64$), Dictyoptera ($E = +0.68$) and Isoptera ($E = +0.68$). Bulbul also consumed Diptera ($E = -0.59$)

and Hymenoptera ($E = -0.22$) since these two orders are abundant in the environment. The negative value for Ivlev index indicates that consumption of these insect orders was because of their abundance and not because it was the preferred prey. The rest of the available prey items (Arachnida, Chilopoda, Demaptera, Ephemenoptera, Gastropoda, Lepidoptera, Odonata, Phasmida and Sihphonaptera) are completely avoided by bulbul in this study ($E = -1$).

4.3.2 Diet of Bulbul at Different Sampling Stations

Figure 4.12 shows that bulbuls in Pelagus National Park and RJ1 have plant materials only in their diet. Station RJ3 have two categories of food, insect only and mixture of plant and insect while RL3 and RB3 have both plants only and insects only food sample. The rest of the sites have all three of the food categories in their diet. This suggest that bulbuls at different sites expressed different pattern of food consumption.

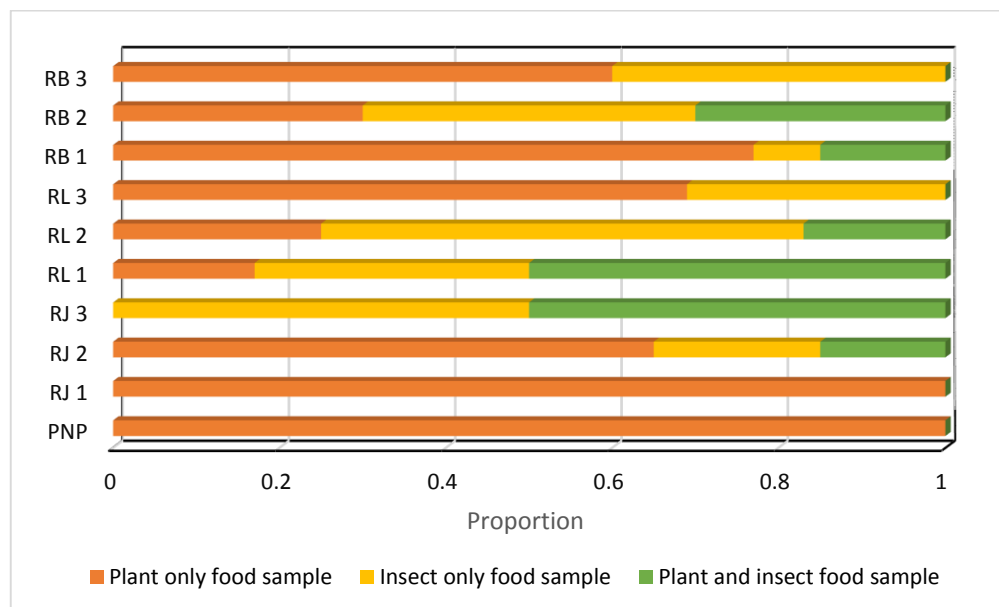


Figure 4.12: Food sample proportions according to station

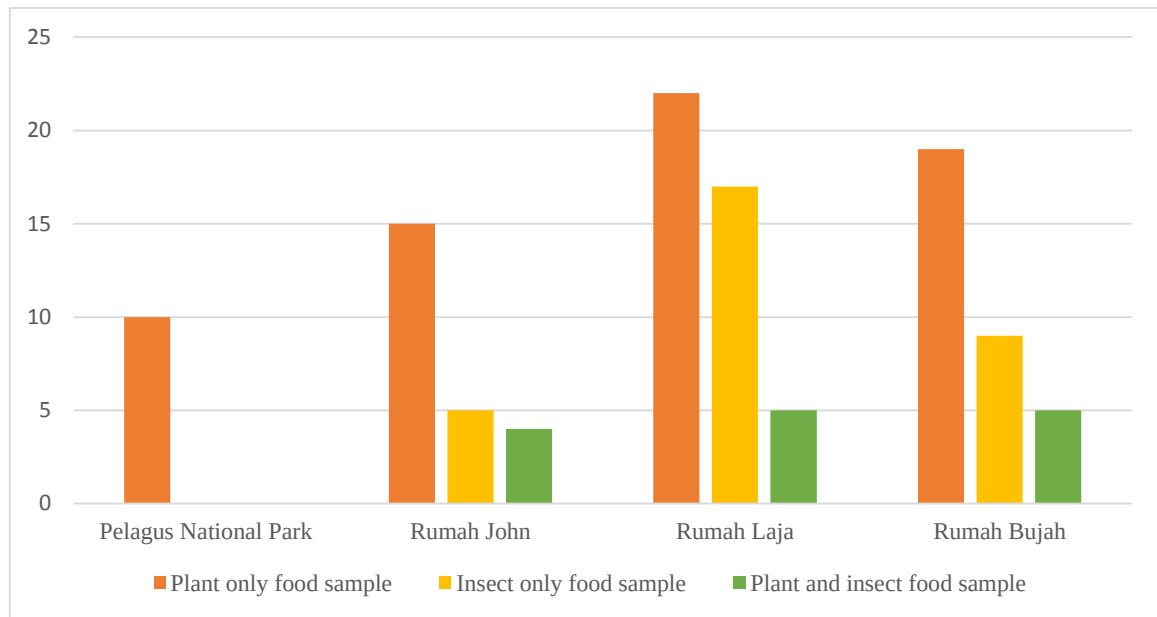


Figure 4.13: Number of food sample based on longhouses and Pelagus National Park

Figure 4.13 shows that the diet of bulbul in the forest behind Rumah John, Rumah Laja, Rumah Bujah and in Pelagus National Park is predominantly consisted of plant material (included fruits, seeds, plant fibre and plant-like material), followed by insect and mixture of plant and insect.

4.3.3 Diet of Different Species of Bulbul

Based on Figure 4.14 samples collected from Black and white bulbul and Grey-bellied bulbul contain only plant materials. Samples from Cream-vented bulbul and Red-eyed bulbul samples have two categories of food - plant only and mixture of plant and insect. Samples from Puff-backed bulbul also have two categories of food, these were plant only and insect only. The rest of the bulbuls consumed all food categories.

The Black and white bulbul have a specific diet of plant only based on three food samples. However only one Grey-bellied bulbul was caught so the data is not sufficient to make a call. The rest of the species have flexible diet.

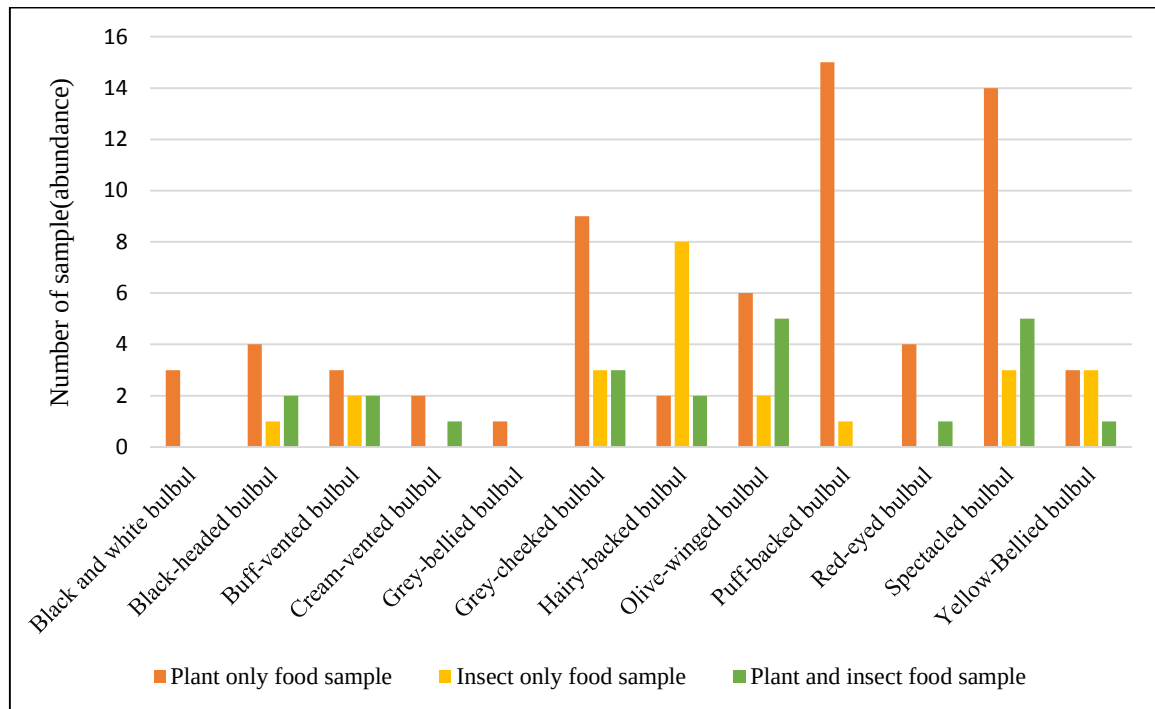


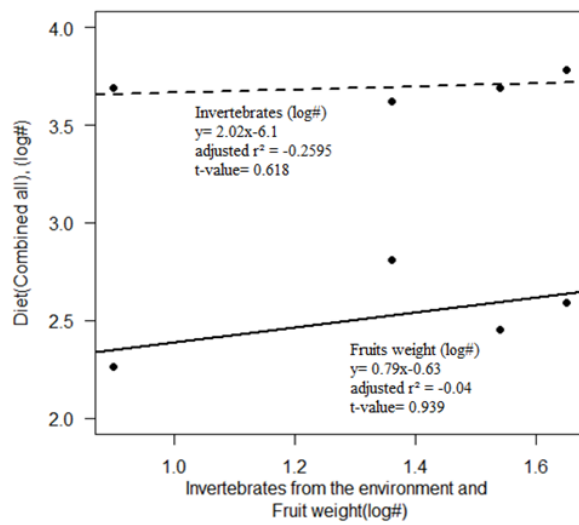
Figure 4.14: Food categories in bulbul diets

4.3.4 Relationship between Bulbul Diet and Food Resources Found in Environment

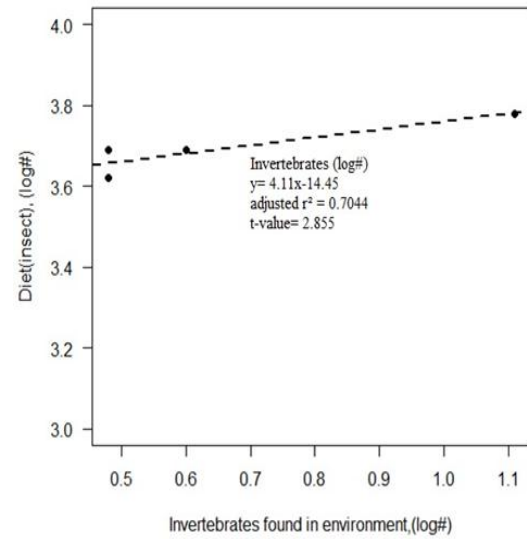
Figure 4.15 shows the bulbul's dietary response to food resources found in the environment. The graph generally shows positive relationships between food samples in bulbul diet and food resources from their environment. Based on Figure 4.15 there are four categories of bulbul's diet composition in this study. The first category is a combination of all the categories mentioned, second is diet of plant where only plant can be detected in individual's

diet, third is diet of insect where only insect can be found and lastly is diet of plant and insect where both of them can be detected.

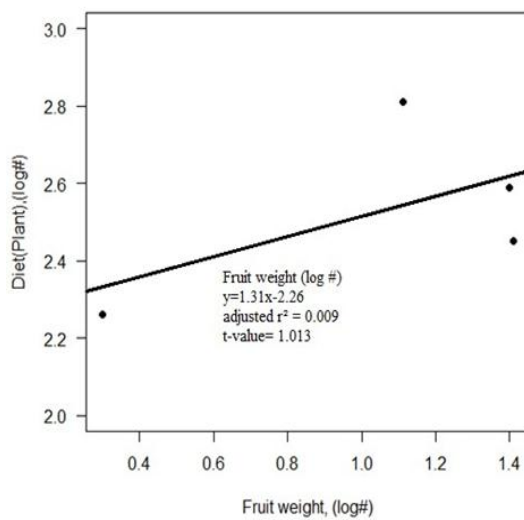
Table 4.13 shows that total sample for all category combined is 111 diet samples. This total is represented by diet (combined all) in Figure 4.15(a). Invertebrate in both Figure 4.15(a) and Figure 4.15(d) shows a slight positive and almost flat slope. This indicate slight positive relationship between bulbul diet (insect) and invertebrates found in environment. Meanwhile the fruit weight showed a positive slope as observed in the graph that indicate a positive relationship between bulbul diet (plant) and fruit weight in environment. Both Figure 4.15(b) and Figure 4.15(c) shows a pronounced positive slope and this is interpreted as a positive relationship between bulbul diet and food resources found in the environment. Figure 4.15(b) showed high adjusted $r^2 = 0.7044$, indicating that insect in the environment explained 70.4% of the variance of insect found in bulbul diet. Overall result showed food resource from the environment does have a positive relationship towards bulbul's diet.



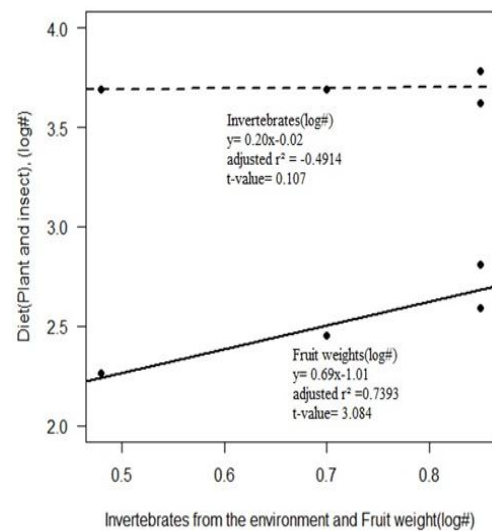
(a)



(b)



(c)



(d)

Figure 4.15: Relationship between food resources found in environment and found in bulbul diet: (a), dash line represent invertebrate from the environment and straight line represents fruit weight from fruits nets; (b), dash line represent invertebrate found in environment; (c), straight line represent fruit weight from fruit nets; (d), dash line represent invertebrate from the environment and straight line represents fruit weight from fruits net

CHAPTER 5

DISCUSSION

5.1 Bulbul Community in Human Modified Habitat of Pelagus

Destruction and degradation of forest is a major environmental problem for Borneo. Gaveau et al. (2014) estimated that in 1973, 75.5% of Borneo was still under natural forest or 558,060 km² of intact old-growth forest (i.e. unlogged). But by 2010, this forest has been reduced by even bigger margin with only 30.2% (168,493 km²) remaining. A major outcome of forest anthropogenic activities such as logging and agriculture is a mosaic of different forest types with varying degree of disturbance. Indeed, disturbed forest is now the major forest type in Borneo (Bryan et al., 2013; Gaveau et al., 2014; Tsujino et al., 2016), and should now be the focus for further research on its ability to support wildlife. According to Castelletta et al. (2000) frugivores and insectivore are specifically affected and vulnerable to extinction after deforestation.

Pelagus, Kapit was selected as sampling site since it has a relatively undisturbed site in Pelagus National Park, and logged forest, secondary forest and agroforest nearby three longhouses. The focus of the study is on the effect of distances from longhouses on bulbul community, and whether the effect is mediated through food resource availability. Bulbul was used as tool to understand what the human modified habitat has to offer to the wildlife that inhabit the forest in Pelagus. Bulbul was selected because it is one of the most important avian seed dispersal among small frugivores (Corlett, 1998a; Corlett, 1998b). The bulbul community has been studied extensively over many years in fields such as phylogeny (Dejtaradol et al., 2016; Shakya & Sheldon, 2017; Shakya et al., 2019), diet (Amit et al., 2015; Lopes et al., 2016), and breeding (Li et al., 2005; Aslan et al., 2018). This study was

carried out to understand the community of bulbul in Pelagus, their food resources and diet under different degree of anthropogenic disturbance.

In this study, a total of 240 bulbuls comprising of 12 species were collected. According to Myers (2016) 24 species of bulbul occur in Borneo and the current study haul of 12 species from a relatively small sampling area represent 50% of the species that occur in Borneo. Thus, the disturbed forest within 500 m from the longhouse has a pretty decent diversity of bulbul, with some sampling locations, for example RJ2, RL3 and RB1, are even better than the less disturbed site PNP. This suggests two things: the minimal impact of isolated human settlement on bulbul diversity and the ability of bulbul to adapt to living in human modified habitat. The key to understanding how they can adapt might be in their diet breadth and availability of their food resources in the sampled area.

The dominant species was Spectacled bulbul with 46 individuals. Phillipps and Phillips (2014) stated that Spectacled bulbul can be found at primary and old secondary forest and is the commonest bulbul of forest understory (Myers, 2016). Based on the findings, Spectacled bulbul can be found mostly at RL3 which is logged-over forest. Based on a study in logged forest by Bing et al. (2014), Spectacled bulbul is one of the dominant species captured at logged forest. Another study at logged forest in Upper Baleh, Kapit also reported Spectacled bulbul in the area (Tuen et al., 2018).

Puff-backed bulbul is the second commonest bulbul in this study with 38 individuals. This species collected the most at RJ 2 where agroforest can be detected there. Myers (2016) explained that this species be found joining others of mixed species in insect hunting and fruit searching with other frugivores at fruiting trees. Puff-backed bulbul has also been reported in oil palm plantation close to the forest edge (Mulyani et al., 2018).

There were three near threatened species recorded in this study, which is Black and white bulbul, Grey-bellied bulbul and Puff-backed bulbul. Black and white bulbul seemed to prefer a lowland dipterocarp, peatswamp, kerangas and lower montane forest up to 1250 m with one record at 3500 m from sea level (Phillipps & Phillipps, 2014) with declining population (IUCN, 2016). In this study, ten individuals of Black and white bulbul were caught with relative abundance of 4.16% out 240 individuals. This species was dominant at RJ2, which have an agroforest type habitat containing a number of fruit trees.

Grey-bellied bulbul is one of the near threatened species and was recorded only in Pelagus National Park in this study. This species is very scarce but occur at primary forest and secondary forest, mostly near the river (Myers, 2016). This may explain why it can be found in Pelagus National Park (PNP) which is primary forest. This species also was recorded in Meliau Basin as common species that inhabit roadside scrub (Sheldon et al., 2009) and Bukit Batikap protection forest at central Kalimantan (Fischer et al., 2016). Puff-backed bulbul is another near threatened species listed in IUCN (2016) and recorded as second highest bulbul species with 38 individuals (15.8%) in the current study. The occurrence of two near threatened bulbul species in PNP reinforce the correct decision by the relevant authorities to gazette 2041 ha of dipterocarp forest as a Pelagus National Park, thereby rendering total protection to the wildlife that are found there and providing place of refuge for wildlife should the local community decide to develop the disturbed forest near their longhouse.

One bulbul species that is critically endangered under IUCN red list (IUCN, 2016) is Straw-headed bulbul but this species was not collected in this study. Its population has been steadily declining although it used to be common in large range area in the 1950s at Southernmost Myanmar, Thailand, Peninsular Malaysia, Sumatra, Java and Borneo (IUCN, 2019). This particular species is a protected species in Sarawak based on SWLPO (1998). This meant

that they are indeed becoming rare due to exploitation as a songbird and marketed at high price (Bergin et al., 2018) and in Java average price of US\$547 were put up for wild-caught Straw-headed bulbul (Chng et al., 2015). This species prefer successional habitat bordering river, streams, mangrove and other wet area and clearance of lowland forest along rivers in Pelagus has probably contributed to its absence.

Agricultural land surrounding human settlements have more richness per point while rainforest contained more unique species (Greenler & Ebersole, 2015). Station RJ2, which is categorized as agroforest, has the highest number of individuals, highest number of recorded species and species diversity. It was located at a ridge; birds crossing from one side of the hill to the other tend to fly lower and have higher chances of getting caught in the net. Other than that, agroforest also provide food resources to bulbul and make them attracted to this site. Secondary forest station RB3 also have high species richness and evenness. This station, located 1000 m from the longhouse, also provided the highest seasonally abundant fruit resources, some of which are probably consumed by bulbuls (Bowen et al., 2007).

RL3 and RB2 has highest similarity with nine shared species. RL3 and RB2 have different forest type, which is logged forest and agroforest respectively, but what make them similar is where mist net was located. The mist nets at both sites were set on a ridge. Birds crossing from one side of the hill to the other tend to fly quite low, increasing their chances of getting caught in the net. That is why both stations showed a high number of species and individuals. Black-headed bulbul was the only species not shared because it was only recorded at RJ2. Based on Phillipps and Phillipps (2014), this species is a fruit-tracking nomad tending to be found when and where fruit resources are available. Lowest similarity was between RB3 (secondary forest) with RJ1 (agroforestry), the reason could be the far distance between them and different forest type.

Avifauna has been widely used to study gradients of human disturbances (Verma & Murmu, 2015; Møller & Dı́az, 2018). Dı́az et al. (2011) considered inhabited house as direct source of human influences. Human presence has a negative impact towards wildlife (Palomino & Carrascal, 2007; McDonnell & Hahs, 2008; Benitez-Lopez et al., 2010) yet animal also benefit from human proximity in the way of resources and as protection against predator (Møller, 2012; Dı́az, 2013). Based on Sodhi (2002), diversity and abundance of bird, the timing of breeding and moulting of bird, ranging behaviour and flock size appear to be affected by food-supply, including those planted by humans. Human disturbance can also affect wildlife behavior, for example, animal become vigilant near human that causes them to forage less and reduce reproduction success rate (Ciuti, 2012). In the current study the stations located 500 and 1000 m generally have higher species richness and abundance compared to stations located 100 m away, suggesting that anthropogenic disturbance influences bulbul community.

Pelagus National Park, a designated control site for this study, recorded 28 individual and 8 species of bulbul. All the near-threatened species in this study, which are Grey-bellied bulbul, Puff-backed bulbul and Black and white bulbul were recorded here. Our observation showed there was little recent disturbance during the study period at this site. Based on similarity test, the bulbul community in PNP showed lowest similarity with stations located 100 m from the longhouse but highest similarity with stations located 500 m from the longhouse.

5.2 Bulbul Food Resources and Their Diets

Bulbul food resources are mainly fruit and insect. Insects are generally rich in protein (Kohler et al., 2019) and have often been used in animal feed industry as protein source for chicken feed in place of the more expensive fish meal (van Huis, 2013). In contrast fruits and seeds that birds often feed on are low in protein but rich in energy due to its high carbohydrate content (Barros et al., 2010). Energy is a critical nutrient for animals because it is required for maintaining vital body function, synthesizing physiologically active compounds and carrying out physical activities needed for survival. Thus, it would be logical for the animal to give priority to meet energy needs by consuming high energy diet. This may be the reason for high number of the diet sample containing plant material, presumably fruit, in the current study. With *Pternandra* sp. being the main fruit collected in this study, it is a possible that *Pternandra* fruit play an important role in the diet of bulbul as the fruit is an intermediate between berries and capsule and some species have fruit dehiscence characteristic (Clausing et al., 2000).

Bulbuls have been reported to switch from being primarily frugivorous to insectivorous (Fogden, 1972; Kerdkaew et al., 2014) depending on which food group is available and abundant, which in turn depend on habitat types and time of the year. Liang et al. (2015), explained that food abundance is essential in regulation of animal physiology and behavior. Sodhi (2002) suggests that food supply can affect the diversity, abundance or density, breeding ecology, body condition and behavior of forest birds.

The current study identified three orders of insect that was preferred by bulbul, which is Orthoptera, Hemiptera and Coleoptera while bulbuls also consumed Hymenoptera ($E = -0.21971$) and Diptera ($E = -0.5949$) based on their abundance. The rest of the arthropods,

including Orthoptera, were avoided. Based on recent study by Okosodo et al. (2016), *Pycnonotus barbatus* (common bulbul) in South Western Nigeria avoids preying on insect from order Orthoptera, Odonata and Dictyoptera in an oil palm ecosystem. This bulbul prefer insect from order Coleoptera, Homoptera, Diptera, Hemiptera, and Hymenoptera. Yellow-vented bulbul (*Pycnonotus goiavier*) in oil palm plantation avoided insects from the order Orthoptera, Odonata, Dictyoptera and Lepidoptera (Amit et al., 2015). This species preferred Coleoptera and Homoptera in this study and also chose insect from Order Diptera, Hemiptera and Hymenoptera as their food. Kerdkaew et al. (2014) study two native bulbul (*Pycnonotus brunneus* and *Pycnonotus goiavier*) in an early successional habitat in Southern Thailand and reported that both species are highly frugivores but consumed some insect from order Hymenoptera and Coleoptera. There are a few species of bulbul that feed on Orthoptera order such as Black-headed bulbul (Lim, 1965), Olive-winged bulbul (Harrison, 1964) and Red-eyed bulbul (Lim, 1965). This may explain the high value of Ivlev electivity index of Orthoptera in this study despite low value in oil palm (Amit et al., 2015; Okosodo et al., 2016) and the differences of habitat can alter this species food preference. Another reason for high Ivlev electivity value of Orthoptera in this study could also be attributed to their small number in the environment (0.52%) yet two samples can be detected from two spectacle bulbuls. Also, Orthoptera have bigger size so bulbul can detect and catch them easily. Bigger prey also gives greater reward in terms of nutrient. More extensive study is clearly needed to better understand bulbul diet and food selection.

According to Wells (1975), Wong (1986) and Lambert (1989), forest bulbul commonly consume figs and other sugar-rich food. Figs bear fruit asynchronously and are always available within the forest landscape but other fruits are seasonal (Hsu & Lin, 1994; Corlett, 1998a). Based on Smythies (1999), there are several possible plants such as

Melastomataceae, Dilleniaceae and Euphorbiaceae that can be found in the fruit nets and probably consumed by bulbul in this study. However, this detail cannot be confirm as the plant part of bulbul diet cannot be identified due to bad condition of our sample.

There are studies which indicated that food-supply affected bird diversity, abundance, body condition, breeding ecology and more (Sodhi, 2002). In this study, Rumah Laja and Rumah John showed a significant association between foods resources with bulbul abundance, suggesting that bulbul depended on the food resource around them. For other sites, there were no relationship or negative relationships, and this may be due to insufficient sampling or they were more affected by other variable or environmental factor in their surroundings. The unsuitable terrain also may make our method ineffective in catching the required number of bulbuls.

Link between food resource and bulbul can be explained even further using diet sample obtained from bulbul through regurgitate, stomach content and fecal extraction. Category of diet sample used are plant only food sample, plant and insect food sample and insect only food sample. This category name were chosen because diet composition of plant materials can't be specify into different feeding guilds because they eat wide range of plant material (included fruit, seed, plant fibre plant-like material) and due to poor condition of the sample so generalization term were used to illustrate the category. The question is whether bulbul eat prey based on its availability in environment or whether they actively search for a specific prey. The diet of bulbul showed a positive relationship toward fruit and invertebrate found in environment. This result showed that food availability in the environment indeed have a positive effect toward bulbul diet. Food availability is important as bird adjusted their diet based on resource abundance. For example, lilac-crowned parrots may alter their food resources use based on temporal variation in resource abundance (Renton, 2001). Food

resources are very important for bird as food restriction has been shown to cause a decrease in basal metabolic rate, body and organ mass and cellular energetic in Chinese bulbul, *Pycnonotus sinensis* (Zhang et al., 2018). Bulbul may also lower its basal metabolic rate and change the weight of certain organ to balance energy requirement in order to survive (Liang et al., 2015). More research is needed to further understand the community, their diet and the resources provided by forest in order to improve knowledge regarding food preferences based on food availability in disturbed environment.

Bulbul in the current study shared similar temporal pattern with fruit weight, indicating there is a positive temporal relationship between them. Naoe et al. (2018) investigated temporal variation in seed dispersal and suggested that temporal variation in community level could be the factor of seed dispersal in temperate forest. They also suggested more studies need to be done to study the effect of temporal variation of fruit abundance or seed dispersal in other ecosystem to understand frugivores phenology. Their result also shows that most important factor influencing the fruit removal by birds were community level fruit abundance and seasonality of frugivores diet. Ramos-Robles et al. (2018) studied the interaction between fleshy fruit and frugivores. This character is an important biotic component and have a specific role in the structure and function of biotic communities. The study also suggested that plant-frugivores was non-random and influenced by fruit traits (for example abundance, phenology, size and water content). Both researches supported the current finding on positive association between food resources and bulbul community and temporal pattern between fruit in environment with bulbul community.

The current study showed that different species of bulbul has different diet composition, some bulbul species are highly selective towards certain prey while others consumed prey based on their availability. For example, Hairy-backed bulbul may prefer Diptera because

this insect was recorded three times in their diet but they probably consume Coleoptera (two sample) and Hemiptera (one sample) based on their availability. Hairy-backed bulbul has the highest abundance at RL2 station and the highest number of insects detected in their diet. High number of food availability found in that site may explained why they attracted to RL2. Many researches had also reported that bulbul eat prey based on the availability of food resources in their area (Linneberg et al., 2010; Kerdkaew et al., 2014; Okosodo et al., 2016). Linneberg et al. (2010) study on Red-whiskered bulbul showed that this bird consumed a wide range of food including nectar, fruit, and insect thus enabling them to adapt to seasonal fluctuation in fruit abundance.

There are also many other factors of food preference that can affect food selection of bulbul, such as season and fruit characteristics. There are also generalist or opportunistic bulbul that can be taken into consideration for further study, perhaps widen even more the biological tool to small frugivores or study all avian. Unfortunately, for some bulbul species the lack of sample limited our ability to make conclusions regarding diet selection. For example, only one individual of Grey-bellied bulbul was captured, and no diet sample could be obtained from this bird.

5.3 Limitation of the Study

Limitation of the study include the difficult terrain and fearsome Pelagus rapid, which restricted access to suitable sites. The riverbank adjacent to the Pelagus National Park was very steep, almost vertical, except near where the Pelagus Resort was located and this limit sampling site to just one location. Access to Rh Laja and Pelagus National Park is through the infamous Pelagus rapid and the ride to these sites using long boats is both scary and dangerous even for experienced boatman.

The mist net we used to capture bulbuls were at most three meters above ground at its highest point, but most bulbuls were seen to use the understory space that is much higher than this. While we tried to maximize our chances of capturing all the bulbul species by setting our nets on a ridge, this was constrained by our experimental design which is to sample at 100, 500 and 1000 m from the longhouse. Only one sampling station was on the ridge, most were on a hill slope.

The food resources sampled, especially using pitfall trap and sticky trap, was probably not representative of insect available to bulbuls which utilize the canopy and understory space above the mist nets. This study encountered one problem where the fruit cannot be identified due to the rotting condition of the fruit or seed is damage. The number of fruit trap and frequency of harvesting (every 10 days) was not enough.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

This study focused on the community of bulbul in Pelagus and their diet. Two hypotheses were investigated (i) bulbul community is affected by distance from longhouses because of the perceived high level of anthropogenic disturbance closest to the longhouse, (ii) availability and composition of food resources in the environment has a strong influence on bulbul diet and therefore its species richness and abundance.

The bulbul community in the study area comprised of 12 species, equivalent to 44% of total bulbul species in Borneo. The dominant species caught in this study was the Spectacle bulbul with 46 individuals and followed by Puff-backed bulbul with 38 individuals. Three near threatened species, Black and white bulbul, Grey-bellied bulbul and Puff-backed bulbul were also recorded in this study. Sites with highest number of individuals is RJ2 (John 500 m) with 48 individuals which also recorded the highest number of species (10 species).

In this study the bulbul community is affected by anthropogenic activities originating from the longhouse community up to 100 m distance from the longhouse. The effect on bulbul community is manifested as reduced species richness, reduced evenness and lower diversity index. The stations located at 500 and 1000 m from the longhouses has higher similarity indices and number of species shared. This supported the hypothesis of this study that the impact of anthropogenic disturbances is greater in areas close to human settlement and less in areas that are further away (500 m and 1000 m) and protected by law (PNP).

Twenty-four families of plants were identified from the fruit samples collected in this study. *Pternandra* sp is the most collected species in this study with 39.16% out of all species. The

most fruits were collected from Rumah Laja 500 m with 668.21 g. The total number of invertebrates collected was 20,037 individuals representing four classes of invertebrate, which are Arachnida, Chilopoda, Gastropoda and Insecta. Diptera is the most abundant insect with total of 11,295 individuals comprising of 56.37% of the total arthropods collected. Station RL2 station recorded the most number of individuals. The amount of fruit collected or arthropod trapped did not show any pattern in respect to distance from the longhouse.

A positive relationship between the food resources and bulbul community was observed at Rumah Laja. On the other hand, lack of or negative relationship for other sites may be due to insufficient samples or they may be more dependent on other variable or environmental factor in their surroundings. Bulbuls also have a positive temporal relationship with fruit availability but not with invertebrate. This may be due to absence of temporal pattern in invertebrate abundance during the study duration.

Diet of bulbul collected via the method of regurgitation, stomach content and fecal extraction showed that from a total of 111 diet samples, 66 samples contain plant only, 23 samples contain insect only and 22 samples contain a mixture of plant and insect. Twenty one samples has seven orders of insect in them. Coleoptera was the most common insect order consumed, followed by Hymenoptera and Diptera. Ivlev's electivity index showed that Orthoptera was the most preferred with electivity index of +0.90 followed by Hemiptera (+0.81). Bulbul also consumed Diptera ($E = -0.59$) and Hymenoptera ($E = -0.22$) based on prey abundance, since these two orders were abundant in the environment. The other prey items (Arachnida, Chilopoda, Demaptera, Ephemenoptera, Gastropoda, Lepidoptera, Odonata, Phasmida and Sihphonaptera) were completely avoided by bulbul in this study ($E = -1$). These results suggested that bulbuls at different sites expressed different pattern of food consumption.

Linear regression of diet against food resources in the environment showed a positive relationship, suggesting that in general bulbul food consumption is influenced by its availability in their environment.

6.2 Recommendation

Here I proposed several recommendations to improve this study, focusing on sampling technique, sampling design, and have a wider biological indicator as well as involvement of the local people in forest resource management. Some of the specific recommendation are as follows:

- (i) Sampling technique need to be improved as we did not cover wide range of insect, for example flying insect that can be caught using aerial nets. Most of the insects sampled in this study reside on the ground but bulbul may be preying on insects higher up towards the canopy. Hence, we also need to target bulbuls and insects in canopy.
- (ii) Sampling technique of fruit also need to be improved by increasing the number of fruit traps and setting them away from the jungle trail. Other improvement includes monitoring the fruit on the trees and observed the ripening phase of the fruit. Increased sampling sites for bulbul and its food resources by including more longhouses as well as in the less disturbed PNP may yield a different result to this study.
- (iii) In effort for conservation and management of forest, local longhouse communities can be involved in forest rulemaking and for further understanding of forest, ecology and for their socio-economic benefit.

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