



Institute of Biodiversity and Environmental Conservation

Diversity and Diet of Babblers (Timaliidae and Pellorneidae): Possible Effects of Anthropogenic Disturbances and Environmental Characteristics at Pelagus, Sarawak (East Malaysia: Borneo)

Pang Sing Tyan

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Diversity and Diet of Babblers (Timaliidae and Pellorneidae): Possible
Effects of Anthropogenic Disturbances and Environmental Characteristics at
Pelagus, Sarawak (East Malaysia: Borneo)

Pang Sing Tyan

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DECLARATION

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

.....

Signature

Name: Pang Sing Tyan

Matric No.: 14010019

Institute of Biodiversity and Environmental Conservation

Universiti Malaysia Sarawak

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ABSTRACT

Disturbed habitats tend to have impoverished bird communities compared to primary forests. This research focuses on the group known as babblers (Timaliidae and Pellorneidae) which are currently understudied in terms of how they persist in a multispecies community and what resource partitioning they utilise when in a continuous disturbed habitat. This study demonstrates a method to measure disturbance by quantifying the level of disturbance in selected sampling stations and was measured based on human and plant components. Based on the disturbance index, the disturbance was found to be varied in different forest types in Pelagus, Sarawak. In addition, the study also examined the babbler community and their potential prey in the areas with varying levels of disturbance; identifying which covariate(s) affect both babblers and prey the most. A total of 1,335 individuals of birds from 106 species were captured throughout this study. Amongst them were 328 babbler individuals, consisting of 16 different species representing from two families (Timaliidae and Pellorneidae). Chestnut-winged babbler was the most common species captured. Of the 17 orders of prey captured, Diptera was the most dominant order, followed by Hymenoptera and Coleoptera. Occupancy of babblers in Pelagus was found to be high ($> 50\%$), despite netting probability being low (20%). Within the nine covariates measured with regards to occupancy and netting probability, eight had almost equal influence on babblers, except for the presence of domestic animals, such as dogs and cats, while canopy cover was the most influential covariate affecting prey abundance at all stations. Resource partitioning among babblers was also investigated by deploying double mist-nets with heights indicated by the ascending shelf (maximum height 3.6 m). The numbers of babblers netted was inversely proportionate to the shelf height of the mist-net, lower shelves (0–0.6 m) recorded the highest catches, implying that most babblers prefer to forage closer to the ground, despite the fact that a majority of

potential prey being caught on sticky traps at 1 m and above. Sampling was conducted four times a year, with an interval of two to three months in between. Results show that the collective babbler abundance was significantly greater between March and April of 2016 compared to the other months in the same year, but there was no seasonal marked on prey abundance. This suggests that foraging activity among babblers could be more active compared to other periods as the foraging time was shorten due to raining. Thus, higher number of babblers were captured. The composition of babbler diets was investigated by analysing sample obtained from 110 regurgitated sample, 58 faecal samples and 27 stomach content. Eleven intact prey items were found from the regurgitated samples, while faecal and stomach content had one each. The results showed that babbler in this study are diet-opportunist. and generalists. Their diets constitute of 11 prey groups. Caterpillars appeared to be the most preferred prey (Jacob's Index), while Coleopterans ranked fourth (behind Orthoptera and Araneida), despite being frequently found in the diet samples. Prey body size was not an important factor affecting babbler prey choice, as the regressions between babbler weight against prey body length had no relation. Instead, babblers may be tracking nutrient content. The preferred prey, caterpillars are rich in phosphorus, while Orthopterans have the highest crude protein content. As human-induced disturbance is inevitable, it is critical to understand how bird groups such as babblers and their prey tolerate different levels of disturbance at the community level, and ultimately mitigate the disturbances that may impact other wildlife.

Keywords: Disturbance, Pelagus, Sarawak, Borneo, bird, trophic ecology, babbler, arthropod

***Pemakanan dan Kepelbagaian Babbler (Timaliidae dan Pellorneidae): Kesan
Kemungkinan Gangguan Antropogenik dan Ciri-ciri Alam Sekitar di Pelagus, Sarawak
(Malaysia Timur: Borneo)***

ABSTRAK

Dalam mengekalkan hidupan komuniti burung, habitat yang terganggu tidak setanding dengan hutan primer. Kajian ini memfokus pada kumpulan burung babbler mengenai kaedah mereka bertahan dalam komuniti pelbagai spesies dan pembahagian sumber (tempat dan makanan) dalam habitat yang terganggu secara berterusan. Kajian ini menunjukkan kaedah mengukur gangguan dengan mengira tahap gangguan di stesen pensampelan terpilih yang menggunakan komponen manusia dan tumbuhan. Menurut indek gangguan, ia menunjukkan gangguan berbeza di jenis hutan berlainan di Pelagus, Sarawak. Kajian ini juga mengkaji komuniti babbler dan potensi mangsa mereka di kawasan yang mempunyai tahap gangguan yang berbeza; mengenal pasti kovariat yang terbanyak pengaruh terhadap mangsa dan pemangsa. Sejumlah 1335 individu burung daripada 106 spesies telah ditangkap sepanjang kajian ini. Babbler terdiri daripada 328 ekor, 16 spesies dan dua famili (Timaliidae dan Pellorneidae). Chestnut-winged babbler, merupakan spesies yang paling banyak ditangkap. Daripada 17 kumpulan mangsa tangkapan, Diptera paling dominasi, diikuti Hymenoptera dan Coleoptera. Kemungkinan babbler yang menghuni di Pelagus tinggi (melebihi 50%) walaupun kebarangkalian penangkapan rendah (kurang daripada 20%). Lapan kovariat mempunyai pengaruh yang hampir sama pada kebarangkalian penghunian dan penangkapan babbler, kecuali dalam kehadiran haiwan domestik seperti anjing dan kucing manakala penutup kanopi hutan adalah kovariat yang paling mempengaruhi potensi mangsa di semua stesen. Pembahagian sumber di kalangan babbler juga dikaji menggunakan jaring berganda dengan ketinggian maksimum 3.6 m. Bilangan babbler yang tertangkap pada jaring dengan ketinggian 0–0.6 m adalah tertinggi,

menunjukkan bahawa babbler mencari makanan berdekatan tanah walaupun kebanyakan mangsa ditangkap pada perangkap pelekat pada aras 1 m dan ke atas. Pensampelan dilakukan empat kali setahun berselang dua – tiga bulan. Hasil menunjukkan bahawa kelimpahan kolektif babbler adalah lebih tinggi pada Mac dan April 2016 berbanding dengan tiga tempoh lain tetapi tiada corak temporal yang ketara untuk kelimpahan mangsa. Aktiviti pencarian makanan mungkin lebih aktif dikalangan babbler. Ini kerana waktu pencarian makanan dipendekkan disebabkan hujan. Justeru, lebih banyak babbler terperangkap. Komposisi diet makanan babbler disiasat dengan menganalisis 110 sampel muntah, 58 sampel tahi dan 27 kandungan perut. Sebelas penemuan mangsa yang belum dihadap didapati dari sampel muntah, manakala setiap satu dari tahi dan kandunagn perut. Hasil kajian menunjukkan bahawa babbler adalah pemakan umum and berkesempatan. Diet pemakanan babbler terdiri daripada 11 kumpulan mangsa. Ulat bulu adalah mangsa paling digemari menurut Indeks Jacob manakala Coleoptera menduduki tempat keempat walaupun paling kerap dijumpai dalam sampel diet. Analisis juga menunjukkan bahawa saiz badan mangsa bukanlah faktor mempengaruhi pilihan pemangsa babbler kerana regresi antara berat badan babbler terhadap bahagian badan mangsa diukur mempunyai korelasi yang tidak ketara. Sebaliknya, pemilihan mungkin berdasarkan kandungan zat. Ulat bulu kaya dengan fosforus, manakala Orthoptera mempunyai kandungan protein yang tinggi. Oleh kerana gangguan yang disebabkan oleh manusia tidak dapat dielakkan, pemahaman kumpulan babbler dan mangsa mereka mengatasi tahap gangguan yang berbeza di peringkat komuniti dan akhirnya mengurangkan gangguan yang mungkin memberi kesan kepada hidupan liar yang lain adalah penting..

Kata kunci: Gangguan, Pelagus, Sarawak, Borneo, babbler, burung, ekologi trofik

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LIST OF ABBREVIATIONS

APT	Antimony potassium tatrare
AM	Apomorphine
Ara	Arachnida
B	Benin
BCB	Black-capped Babbler <i>Pellorneum capistratum</i>
BRB	Chestnut-rumped Babbler <i>Stachyris maculata</i>
BSTB	Bold-striped Tit-babbler <i>Macronous bornensis bornensis</i>
BTB	Black-throated Babbler <i>Stachyris nigricollis</i>
CAN	Canopy
Cat	Caterpillar
CBSB	Chestnut-backed Scimitar Babbler <i>Pomatorhinus montanus</i>
cc	Cubic centimetre
cm	Centimetre
Col	Coleoptera
CWB	Chestnut-winged Babbler <i>Stachyris erythroptera</i>
DBH	Diameter breast height
Der	Dermaptera
Dic	Dictyoptera
Dip	Diptera
DIST	Distance
Eph	Ephemenoptera
ELE	Elevation
FB	Ferruginous Babbler <i>Trichastoma bicolor</i>
FBTB	Fluffy-backed Tit-babbler <i>Macronous ptilosus</i>

FT	Forest type
Gas	Gastropoda
GHB	Grey-headed Babbler <i>Stachyris poliocephala</i>
g	Gramme
HB	Horsfield's Babbler <i>Trichastoma sepiarium</i>
Hem	Hemiptera
Hym	Hymenoptera
ind.	Individual
Iso	Isoptera
Lep	Lepidoptera
LLD	Leaf litter depth
MAN	Human
MB	Moustached Babbler <i>Malacopteron magnirostre</i>
ml	Milimetre
Myr	Myriapoda
Ng.	Confluence
no.	Number
Odo	Odonata
Ort	Orthoptera
PET	Pet
Pha	Phasmida
PL	Pelagus
PNP	Pelagus National Park
ppm	Part per million
PR	Peraran
Rh	House

RCB	Rufous-crowned Babbler <i>Malacopteron magnum</i>
SCaB	Sooty-capped Babbler <i>Malacopteron affine</i>
SCB	Scaly-crowned Babbler <i>Malacopteron cinereum</i>
Sip	Siphonoptera
sp.	Species
STB	Short-tailed Babbler <i>Trichastoma pyrrogenys</i>
TP	Tree proportion
WCB	White-chested Babbler <i>Trichastoma rostratum</i>

CHAPTER 1

GENERAL INTRODUCTION

1.1 Habitat Disturbance

An ideal habitat provides an optimal condition for living. With human presence nowadays, many habitats are disturbed in many ways. The disturbance is a physical force, either natural or anthropogenic, that alters or damage natural ecosystems resulting in mortality of organisms or loss of biomass (Smith, 1996; Battisti & Fanelli, 2016). The impact of disturbances on organisms and ecosystem depends on its nature, intensity, frequency and scale (Smith, 1996; Battisti et al., 2016). It could be a direct effect of which the most severe is the mortality of organism or indirect effect through a medium such as a habitat that reduces resources that supply the organism, or through other aspects of animal life, for instance, reproduction. Intensity is the concentration of the disturbance power and force that could either affect the entire or parts of the population of a certain species to be killed or removed. Frequency refers to how often a disturbance(s) occurs in a duration of time. A scale of the disturbance depends on the quantity of organism that is affected. For example, small scale disturbance may damage or kill only a few trees or animals.

Natural disturbances include those caused by earthquake, severe wind and flood, fire and landslides (Battisti et al., 2016). An area that destroyed by any natural disaster which the functions of the area would almost fail completely, or regenerate is almost impossible due to the scale is too large and at high intensity. Among the natural disturbances, flood and fire are the most frequent in Borneo, and of the two, a fire has the most devastating effect, not only on ecosystem and species but the air quality as well (Smith, 1996). For example, two relatively recent episodes of major fire (1982–83 and

1997– 98), burned millions of hectares of forest, killed and displaced thousands of animals and released millions of tons of carbon dioxide into the atmosphere (Heil & Goldammer, 2001; Varkkey, 2011). Unlike other regions of the world, Borneo forest fires have been attributed to open burning by plantation developers (Varkkey, 2011), thus coming under the category of anthropogenic disturbance. A controlled fire has elsewhere been used as management tools to revitalize the soil and manage the ecosystem, for example in Australia (Olsen & Weston, 2005).

Anthropogenic disturbances, in general, are due to activities that humans engage in to sustain livelihoods, enhance the quality of life and increase political influence. The major activities impacting wildlife include harvesting of forest resources in particular timber (Hon & Shibata, 2013), cultivation of land especially for plantation agriculture (Koh et al., 2008; Edwards et al., 2014; Amir et al., 2015) , establishment of recreation areas, such as golf courses, and expansion of urban areas (Li et al., 2012). A major impact of these disturbances may be the loss and degradation of habitat for wildlife, being damaged to the extent that it no longer exists or loss of major functions (Hornby, 2000). A degraded forest is one whose capacity to sustain ecological processes and biodiversity has been reduced as a result of anthropogenic disturbances (Drummond & Taylor, 1997). Table 1.1 shows representative cases ASEAN countries, caused by natural disasters and human activities. South-East Asian regions, incidentally, are known for the higher rates of deforestation compared to other region (Laurance, 1999; Sodhi et al., 2004; Reynolds et al., 2011).

Table 1.1: Areas affected by natural disasters in ASEAN countries and the degraded forests of Borneo.

No.	Affected area			Degraded forest		
Nation	Tacloban, The Philippines	Pokhara, Nepal	Palu, Indonesia	Sarawak, Malaysia	Sabah, Malaysia	Kalimantan, Indonesia
Year	2013	2015	2018	1950	1960	1970
Type of disturbance	Typhoon Haiyan	Earthquake	Tsunami	Deforestation and agriculture conversion		

The scale of habitat disturbances in Borneo has attracted criticism as it is one of the world's biodiversity hotspots (Myers et al., 2000; Mittermeier et al., 2011). It is home to at least 3,453 species of plants (Jawa & Chai, 2007), 948 species of butterflies; 674 species of birds, both migratory and residential (Lepage, 2018); 253 species of mammals (Phillipps & Phillipps, 2014); and 180 species frogs (Inger et al., 2017). The loss of wildlife habitat in Borneo has accelerated mainly resulting from the human activities, especially logging and shifting cultivation (Edwards et al., 2011; Contantini et al., 2016).

1.1.1 Logging

Driven by international demand for tropical timber, Sarawak's log production and export increased rapidly from the mid-1970s peaking at 19Mm³ in 1991 (Hon & Shibata, 2013). This has contributed significantly to Malaysia log production (Figure 1.1). Up to 2009, nearly 80% of the forest in Sabah and Sarawak has been degraded (Sodhi et al., 2004; Edwards et al., 2011; Bryan et al., 2013; Gaveau et al., 2014), mainly due to logging and agricultural activities. The scale and intensity of logging can be indicated by the density of logging road and Sarawak recorded the highest density of logging roads, at 0.89 km km⁻² (Gaveau et al., 2014).

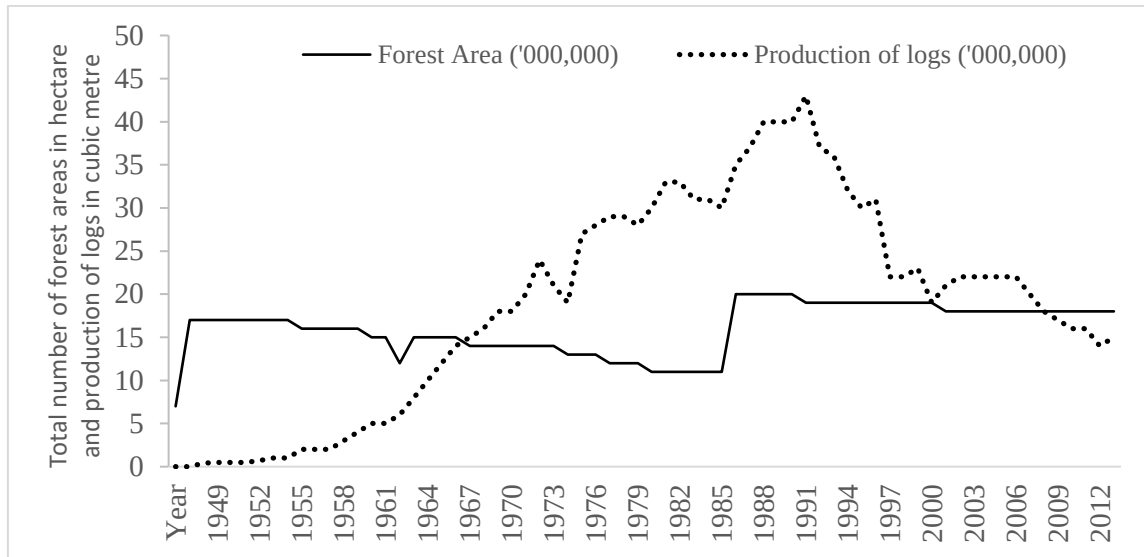


Figure 1.1: Total production of logs in relation to the forest areas in Malaysia, from 1949 to 2012 (Department of Statistics Malaysia, 2014).

During its heydays (1970 – 2005), the number employees in the logging industry, including from site survey to tree-felling, increased tremendously as logging activities expanded into the interior of Sarawak. The logging industry, benefitting from overseas demand for tropical timber and favourable government policies, became the mainstay of the economy of Sarawak for over 40 years (Gaveau et al., 2014). From the environment standpoint, as primary forests were converted into logged forests, soil erosion became common, rivers became heavily silted, water supply and river transport were disrupted and aquatic life, especially fish, suffered from poor water quality (Drummond & Taylor, 1997). Logging roads also opened access into the interior for hunters and provided alternative access to the local people to cultivate lands (Bennett & Gumal, 2001).

In addition, logging also alters forest characteristics. The canopy gap, the composition of trees, the sizes of the trees, and the undergrowth of the forest are one of the alterations to be seen in a logged forest. Large trees that were cut fell onto and destroyed or

damaged adjacent trees leading to expansion of the canopy gap (Johns, 1988; Smith, 1996). Canopy gaps become smaller in regenerated forests, with small trees and broad leaves that cover the upper parts. Extraction of timber trees provides space for the growth of the wild pioneer species such as bamboo (under family Poaceae), *Macaranga* sp. and *Dillenia* sp. (Goodale et al., 2012; Isa et al., 2015). Thus, post logging forests have different tree composition and new growths are most likely small in sizes in terms of diameter at breast height. Forest undergrowth change due to the intensity of sunlight penetrating to the forest ground through the expanded canopy gap after the trees are felled. The rate of decomposition leaf litter is thus decreased due to the reduced number of invertebrates on the forest floor in disturbed forests than that in primary forests (Yeong et al., 2016).

Conscious of the damaging accumulative environmental impact of the logging industry and recognizing that timber resources are depleting, as well as continued pressure from international and local environmental groups, the government of Sarawak has come up with the policy in 2014, of not renewing timber licences that have expired, as reported on March 26, 2016 by local newspaper The Sun Daily. Long before this happened, the more accessible lowland areas have been logged many times and then abandoned after all the timber trees had been extracted or became part of an agricultural landscape, either through shifting cultivation or oil palm plantation.

1.1.2 Shifting Cultivation

Shifting agriculture has been practised by the native tribes of Borneo for thousands of years, based on the finding of rice ash in sediment deposited in Loagan Bunut (Hunt et al., 2006). Shifting agriculture, also known as “slash-and-burn” agriculture for planting hill paddy, has been practised by the Ibans since time immemorial, and it is the mean through

which they acquire land for their family and over generations (Kendawang et al., 2005). They also established usufructuary right over the secondary forest that follows hill paddy cultivation (Freeman, 1955). As the Iban become acquainted with cash crop economy, especially after the formation of Malaysia, they also participated in government schemes involving cash crops, particularly, rubber, cocoa and pepper (Mertz et al., 2013).

Shifting cultivation is still conventionally practised in many areas of Sarawak. The attraction of an income-generating job in urban areas, however, has changed the demographic composition and dynamics of land use in much of the rural areas of Sarawak. Kapit and Sibu are the major urban centres in central Sarawak and has triggered a massive rural-urban migration, especially among the young generation (Ichikawa, 2007). The number of people that remain in the longhouses is decreasing (Ichikawa, 2007), especially among Iban tribe that live along rivers in the region of Pelagus, Kapit. Many farmlands remained fallow and even the cash crops planted earlier were not tended or harvested (Ichikawa, 2007; Mertz et al., 2013). Farming in the areas adjacent to the longhouse is most preferred by the older folks. The farming areas in a distant primary forest is no longer convenient for farming (Battisti et al., 2016).

The overall outcome of these anthropogenic change is a landscape comprising a myriad of habitat types of different quality, thereby creating disturbance variations that are dynamic in nature. It presents a special challenge to animals that need to continually adjust to varying condition of their habitat.

1.2 Animal Responses to Habitat Disturbance

Animals' responses to anthropogenic activities are varied. Table 1.2 shows the wide array of animals ranging from the large mammals to small invertebrates respond to the anthropogenic disturbances. A review on the relationship of ants with the ecosystem in many countries including Australia and Costa Rica concluded that ants responded negatively to the practices of agriculture, such as the irrigation, drainage and fertilization would result in the reduction of ant species richness and the biomass. Nevertheless, ants can bounce back and increasing the population after a few years of the agriculture has taken place (Folgarait, 1998).

The implications of the responses from studies listed in Table 1 show that some taxa of animals show negative responses, such as the decline in population resulting from the emigration from the disturbed areas or the decrease of the growth rate (Gibbs, 1998; Zilhona, 2003; Hogsden, 2004; Cole, 2014; Cheyne et al., 2016). This, thus, may lead to the population reduction and eventually local extinction. In contrary, the resilience of certain species not only enable them to survive and adapt to the changes but also preferentially inhabiting, utilising and even promoting community comprising different or invasive species in those disturbed areas (Gibbs, 1998; Parry et al., 2007; Savitha et al., 2008).

Table 1.2: List of studies focused on animal response to disturbances worldwide.

No	Citation	Locality	Taxa	Types of disturbances	Response to disturbance
1	Gibbs (1998)	New Haven County, Connecticut, U. S. A	Amphibian	Forest fragmentation by urbanisation	Amphibian species have varying responses to disturbances. Fragmented habitats are adaptable to <i>Plethodon cinereus</i> (Redback Salamander) and <i>Pseudocris c. crucifer</i> (Spring peeper), intermediate-adapted by <i>Rana sylvatica</i> (wood frogs) and <i>Ambystoma maculatum</i> (Spotted Salamander) but avoided by <i>Notophthalmus v. viridescens</i> (Red-spotted Newts).
2	Zilihona (2003)	Udzungwa Scarp Forest Reserve, East African	Invertebrate	Logging, collection of forest produce, plantation and construction of hydropower dam	High intensively disturbed habitat such as heavily logged forest and exotic pine plantation were reported housing distinctive arthropod community. Many Coleoptera families were missing in disturbed areas.

Table 1.2 continued

					A regenerated post-disturbed area was said promoting the development of new Coleoptera community which its species composition is distinctive from those of the in the nearby virgin forest.
3	Hogsden & Hutchinson (2004)	South-eastern Ontario, Canada	Butterfly	Urbanisation	15 of 26 observed species were not found in disturbed sites. 28 % of observed species adapted to the disturbance whereby 58% avoided it.
4	Vera & Rocha (2006)	Ilha Grande, South-eastern Brazil	Small mammal	Post-farming effect	Adaptation, development of new behavioural strategies and breeding rate are also adversely affected Species are robust to habitat alteration, to the disturbances and some will rebound when resources, such as food, becomes abundant again,
5	Parry et al. (2007)	North-eastern Brazilian Amazon	Endotherm	Large-scale exotic tree plantations	Ungulate browsers and small primates were abundant; whereby frugivores and granivores large-bodied primates and

Table 1.2 continued

					birds are low in a secondary forest than primary forest.
6	Savitha et al. (2008)	Bangalore, India	Ant	Urban land use	Not only the ant diversity of disturbed sites was high, but those sites supported rare species. Litter and canopy cover is significantly affecting the ant species richness.
7	Schreven, (2013)	Sebangau Catchment, Central of Kalimantan	Ant	Logging	Species richness of ant was lowest in forest gaps followed by that of in forest edge and highest the forest interior. Species similarity is higher at both forest gaps and forest interior, indicating that different species would prefer at different forest types. Results in forest gaps show that less speciose of ant species further away from the forest, whereby higher number of species found when it gets closer to the forest.

Table 1.2 continued

8	Cole et al. (2014)	The Ecuadorian Andes	Frog	Land use – a mixture of pasture	Seven <i>Pristimantis</i> species were negatively responded to the disturbances Growth rate and number in the population, and the apparent survival were significantly lower in disturbed areas
9	Cheyne et al. (2016)	Indonesian Borneo	Large mammal <i>Neofelis diardi</i> (clouded leopard), <i>Macaca nemestrina</i> (Pig- tailed Macaque), <i>Sus barbatus</i> (Bearded Pig).	Burning or land alteration for urbanization or agriculture	The disturbed forest is not preferred The reduction of the richness of these species was reported to be correlated to the disturbance level
10	Mohd-Azlan et al. (2018)	Kubah National Park, Sarawak	Mammals	Road effect	Ungulates and civets were camera- trapped the most at the distance 5 – 100 m from the road whereby carnivores found at 100 – 200 m. Few species show their tolerances to the disturbance by present at 5 – 100 m frequently.

Birds have been widely studied as a group, as they are diverse, particularly on Borneo, with a total of 674 species recorded, including migratory species (Lepage, 2018). The group comprises members which can be comparatively abundant, visible and relatively easy to be located and captured compare to many other animal taxa (Gray et al., 2007).

Studies on the responses of birds to the disturbances induced by human activities have been carried out worldwide, for example, post- and current anthropogenic disturbances were reported to have affected bird community the most in various ways (Zakaria, 2000; Zakaria et al., 2005; Murphy & Romanuk, 2014). Table 1.3 shows the responses of birds to human-induced disturbances. It demonstrates that birds are sensitive to environmental disturbances and respond to it accordingly. Highly sensitive birds migrated or left disturbed areas, otherwise, birds with lower sensitivity would adjust and adapt to the disturbances. Certain level or source of disturbances might trigger the endurance of a bird in deciding to leave or to stay. Insect-eating species for one, are known to be sensitive to environmental disturbances induced by a human, as summarised in Table 1.3 and need to be investigated, especially why they seem to thrive in various habitats with different degree of disturbances.

Table 1.3: List of the respective responses of birds to disturbances.

No	Citation	Locality	Disturbance-related drivers	Response to the disturbance
1.	Norries et al. (2003)	North-east Iowa, USA	Logging and pasturing practices	A forest with frequent disturbance sustains higher number of permanent residents while less frequently disturbed forest housed more area-sensitive species. A forest with frequent disturbance is preferable to bird species that migrate short-distances and nest on the ground. Although disturbed forests sustain higher number of species, native forest sustains rare species.
2.	Crooks et al. (2004)	California, USA	Fragmentation and urbanisation	Urban-adaptable species were abundant in fragments rather than unfragmented habitats, but urban-avoider species were low in fragmented areas. Bird abundance was not different along the distance gradient in the urban matrix near Mission Trails Regional Park.
3.	Gomes et al. (2008)	Talamanca Mountains, southern Costa	Commercial logging and human colonisation	Species favouring forest (undisturbed habitats) and avoiding forest (disturbed habitats) are identified.

Table 1.3 continued

		Rica		The density of large frugivores declined in a disturbed area whereby small frugivores increased.
4.	Barlow et al. (2006)	Amazon, Brazil	Logging, fire and fragmentation	Composition of understorey birds in a logged forest is distinct from those of undisturbed forest. Compositions of understorey birds are markedly low in fragmented habitat, once-burned forest and twice-burned forest.
5.	Battisti & Fanelli (2016)	Latium region, central Italy	Various land uses, eg. railways, salted motorways, trampled vegetation of paved area	Bird species are adaptable in areas with moderate degree of disturbances; they are generalists; while certain species restricted to stable and mature habitats with least disturbances which are specialists.
6.	Devictor et al. (2008)	France	Human-transformed habitats	Distribution of habitat specialist-birds were found restricted in fragmented and disturbed areas. Fragmentation and disturbances in an area are not the obstacles to the distribution of generalist birds.
7.	Werema (2015)	Mangala Forest Reserve, Tanzania	Forest fire	Total number of species and individuals captured pre-fire were 22 and 54. The recovery of species and

Table 1.3 continued

				individuals eight months post-fire are only 50% and 63%, respectively.
8.	Posa & Sodhi (2006)	Subic Bay, Philippines	Urbanisation and agriculture	Bird species richness was highest in least disturbed sites (forested area), followed by moderately disturbed suburban and the most disturbed rural habitats
9.	Burivalova et al. (2015)	Tropics	Logging	The abundance of fruits and insects-eating birds declined in logging area, and the body mass of birds captured decreased. Nectar- and grain-eating birds surprisingly responded positively in terms of number but only last for 20 years, after which it reduced to levels lower than before logging.
10.	Amir et al. (2015)	Teluk Palima Garang-Pulau Carey and Banting-Jenjarom, Selangor, Malaysia	Monoculture plantation	Species of birds vary in response to different land use. Undisturbed area, such as mangroves houses higher diversity of birds compared to severely disturbed oil palm plantations.

Table 1.3 continued

11.	Wong (1986)	Pasoh Forest Reserve, Negeri Sembilan, Malaysia	Virgin forest versus regenerating understory	Availability of fruits is greater in a primary forest than in disturbed area whereas the number of foliage arthropod were similar to those of primary forest but period with fewer arthropods in disturbed forests was 120 days longer than in the primary forest. Higher diversity of birds in primary forest probably due to long periods of arthropod absence
12.	Lambert (2013)	Ulu Segama Forest Reserve, Sabah, Malaysia	Selective logging	Number of trogons, woodpeckers, wren-babblers and flycatchers declined in disturbed areas

Being the largest guild among Bornean avifaunal assemblages, insectivores accounted for 60% of all bird species, while 40% were the combination of other guilds (Phillipps & Phillipps, 2014). Babbler, an insectivorous bird group with 32 species reported from Borneo belong to two families, Timaliidae and Pellorneidae. Insectivorous birds reported to be sensitive to fragmentation of their habitat, manifested as decrease in number after logging had taken place (Barlow et al., 2006; Ghasemi & Zakaria, 2008). Nevertheless, Bornean babblers not only occupying most of the habitat types ranging from the severely disturbed agriculture plantation, logged-over forest, regenerated secondary forest (Zakaria, 2000; Ghasemi & Zakaria, 2008), lowland mixed dipterocarp forest (Razak et al., 2015) and to high land area (Pang et al., 2017), but also survive in the severely-disturbed habitats thrived (Styring et al., 2016).

Babblers are morphologically and behavioural similar. The part between the foot and tibia is long, which make them easily recognisable from other species. They are commonly brownish in colour and are usually active near the ground. Considering the optimal foraging theory which babblers know what they consume on, and where do they forage in order to maximize the net energy gained without excessive time and energy spent (Cowie, 1977; Batistia et al., 2001). They forage in the undergrowth and search prey in the confined understorey area. Nevertheless, babblers differ from each other. Does differences in morphology contributes to their adaptability and resilience in different habitat types? Previous studies reported that the sympatric babblers partition resources to minimise competition and promote coexistence (Mansor et al., 2015; Styring et al., 2016; Mansor & Ramli, 2017).

1.3 Research Questions, Objectives and Hypotheses

Anthropogenic disturbance has been said to affect biodiversity adversely through hunting and habitat loss or degradation. The babblers are not affected by hunting because they lack attributes, for example most of them do not have melodious songs, that make them commercially attractive. Habitat loss is devastating to most birds, including babblers, but habitat degradation does not seem to have any detrimental impact on babblers, in fact some babblers thrived in it. Little is known about the mechanisms that enable them to thrive in these degraded forests. Could it be the availability of food resources, their foraging strategy or resource partitioning?

With regards to the effect of disturbance, the following questions are asked,

- 1) Do babbler assemblages respond to disturbance?
- 2) How do they partition resources in a forest, both with respect to space and food?
- 3) Which habitat characteristics influence their occurrence? What aspects of the habitat do babblers respond to?
- 4) What diets (for example arthropods) are available to babblers in the forests?
- 5) Can babbler diet be analysed by eat by examining regurgitated or faecal samples?
- 6) What factors motivates them to feed on a prey?

This study has four primary objectives. Firstly, it aimed to determine the disturbance variations among 10 sampling stations in which one is located at a national park and nine others in the forested areas behind an identified longhouse. Forest type

identification and environmental condition assessments were conducted in order to develop an index in determining the disturbance levels at each sampling station. Secondly, this study determined the babbler community and the composition of arthropods along the disturbance variations in degraded forests. The third objective was to examine the diet of the species of babblers, based on identifiable parts in regurgitated and faecal samples. The fourth objective of this study was to determine the nutrient contents of arthropod prey.

The hypotheses of this study were

- 1) disturbance variations exist in the areas which varied in topographically and level of human utilisations,
- 2) the ability of babbler species to co-exist depends on how they partition their use of space and food resources and hence disturbance is thought to affect babbler assemblages through these two factors and,
- 3) babbler prey show responses to the disturbance variations which may potentially influence the occurrence of their predator
- 4) babbler diet preferences depend on the availability of potential food resources and their nutritional values.

1.4 Arrangement of Thesis

This thesis contains six chapters. Chapter 1 discusses the background and justification of the study. Chapter 2 to Chapter 5 are the experimental chapters based on field and laboratory investigations. The thesis commences with the quantifying the disturbance variations with respect to different environmental characteristics in Chapter 2. Chapter 3 investigates how babblers fit in the understorey avifauna assemblages under

disturbance variations, followed by Chapter 4 on the diversity and abundances of potential arthropod prey. Chapter 5 investigates babbler diets based on regurgitated, faecal and stomach contents, and nutritional analysis of the arthropods collected from the field. Chapter 6 discusses and link the findings of the previous chapter and lastly, Chapter 7 concludes with a synthesis of this study, mentioning limitations and recommendations for future study.

CHAPTER 2

QUANTIFYING ANTHROPOGENIC DISTURBANCE VARIATIONS

2.1 Introduction

2.1.1 Anthropogenic Disturbance

Human presence, through their activities in an area, invariably causes alteration to ecosystems. Logically, the intensity of anthropogenic disturbance is expected to be the highest in areas near settlements and lowest when it is distant from them. Longhouse settlements are mostly inhabited by the older generation or by primary school-going children. The older folks prefer to plant quick yielding vegetables closer to their longhouse (Pedersen et al., 2006), and by doing so, spend shorter time and effort in travelling. Disturbance variations are thus expected to exist. Habitat disturbances arising from the anthropogenic activities include forest clearing and resource harvesting or activities of their pets (dogs and cats) which may influence the occurrence of wildlife (Sodhi et al., 2004; Woinarski et al., 2018)

In the context of Sarawak, forest clearing refers to the removal of vegetation by slashing and burning for the purpose of planting hill paddy. This planting activity is carried out from an area to another, thus it is referred as ‘shifting agriculture’ (Tisen, 2001). Clearing of a forest for shifting cultivation by slash-and-burn has been practiced by the Ibans for centuries (Tisen, 2001; Ichikawa, 2007; Sanggin et al., 2016). *Oryza sativa* (Rice) farming is the most common crop planted. The Iban in Pelagus also plant *Solanum ferox* (Terong Asam), *Sauropus androgynus* (Cangkuk manis), *Vigna unguiculata* (long bean), *Manihot esculenta* (cassava), *Capsicum annuum* (chilli pepper), *Solanum* sp. (cucumber),

Cucurbita sp. (pumpkin), and *Zinger officinale* (ginger). Vegetable planting usually takes place in the area adjacent to the longhouses or further away but is always within comfortable walking distance.

Commodity planting, such as rubber, started in 1997 (Ichikawa, 2007) but has been inactive in the past ten years. In Pelagus, rubber trees can be easily seen in the forested areas, but rubber tapping is no longer carried out, due to the commodity price of rubber being lower than before. Subsequently, most rubber farmers have switched to planting pepper, as the market price of this commodity is high. White pepper prices were RM 50,000 per tonne and black pepper RM 30,000 per tonne in July 2015 (source of price information from Pepper Marketing Board, reported on March 16, 2018 by local newspaper The Star Online). Not all the lands with rubber have been replanted. Some are left abandoned, with the owners of the land living away from the village with no intention to plant.

Commercial logging in Sarawak is believed to have started after the year 1946, after Sarawak was handed over to the British government (Drummond & Taylor, 1997). In Kapit, the harvesting of logs took place in Pelagus in the early of 1960's (Braggs, 1993) until present, and logging is still being carried out at Putai and Ulu Baleh. Large-scale forest clearing in Sarawak is generally attributed to commercial logging (Bryan et al., 2013; Gaveau et al., 2014), the locals then use the logging roads to access the interior for shifting cultivation, collect non-timber forest product (NTFP) and hunt wildlife. Prior to this, they use boats and rivers to access the interior, hence before commercial logging took place shifting cultivation are located along the river. Timber extraction, collection of NTFP and hunting of wildlife are part of resource harvesting.

The lifestyle of an Iban is closely associated with forests. In addition to big-scale log harvesting, local people also extract wood from the forest occasionally to build their long boat as this is their main means of transportation. Rattan and palm leaves are used for weaving daily necessities such as traditional broad hat (called '*tangin*'), mats, basket, back- and hand-bags which would generate side-income for their household. Local people also harvest forest produce for food occasionally. Wild ferns, fungi and young shoot of *Eugeissona insignis* (Pantu) are food of choice. Seasonally, they visit planted trees, such as *Durio* spp. (Durian), *Nephelium* spp. (Rambutan), *Canarium odontophyllum* (Dabai), *Baccaurea motleyana* (Rampai) and *Garcinia mangostana* (mangostene) when these bear fruits. The number of fruit trees and food plants could indicate the number of visits local resident make to the forest, which, in turn, may cause disturbance to wildlife, especially if these visits coincide with opportunistic hunting of wildlife that come to feed on the fruits.

Wildlife hunting is practiced by most native tribes in Sarawak. Wild meat is their main source of protein, in addition to fish. Blowpipes, '*sangkoh*' and knives were used for hunting, which occurs in group or by solo hunter. Hunting became widespread and active when the interior areas were accessible through logging roads established by logging companies (Bennett & Gumal, 2001). At present, despite wildlife hunting being prohibited or restricted by laws, the meat of wild animals such as civets, wild boars and monkeys are seen on sale in wet markets in Sarawak, including at Kapit (Kirupaliny & Mohd-Azlan, 2012).

Wildlife hunting is assisted by domestic dogs from longhouses. During no hunting days, dogs and cats that roam in the village compound and often go into the forest to hunt small animals. Free-ranging dogs and cats were reported to hunt other smaller animals,

such as opossum and rodents in Piracicaba, south-eastern Brazil (Campos et al., 2007). In Australia, 272 million of birds were killed and consumed by cats each year, with about 99% of the birds being native species (Woinarski et al., 2018). Predators affect their prey directly by killing them or indirectly by instilling fear thus changing their behaviour. In a study of wild sheep, Benoist et al. (2013) found that predation risk (perceived or real) affects the behaviour of sheep by making them highly vigilant, often at the cost of other life history requirements, such as feeding and mating. Human hunters, cats and dogs may therefore affect their prey in the same manner.

2.1.2 Assessment of Anthropogenic Disturbance

Human disturbance is a widely studied topic as human presence is almost everywhere around the globe. Table 2.1 shows selected previous studies on disturbance at various localities, focusing on the disturbance sources including mainly environmental variables, such as temperature, humidity, light density and bare soil; plant component like leaf litter depth, density of trees and girth of the trees. In addition, the list also includes methods used in analysing the disturbances globally. Of the 14 studies worldwide, five focused on Southeast Asia region and only two focused on Borneo. The two studies conducted on Borneo did not examine the possible effects of disturbance on the faunal diversity.

Table 2.1: List of previous studies on human-induced disturbances.

No.	Citation	Locality	Methods used
1.	Karr & Kimberline (2003)	Hanford Nuclear Reservation South-eastern Washington State	Study subjects are invertebrates, such as Diptera, Acarina, the predators, detritivores and ground-dwellers. Abundance of invertebrate taken as metrics, transformed on a standard scale. Accumulation of scales is multi-metric index. The higher the value of multi-metric index is the lower human disturbance it has.
2.	Peres et al. (2006)	Brazilian Amazonian	Remote sensing technique was used, and the images obtained reviewed from previous studies to detect anthropogenic disturbances, disturbances due to logging.
3.	Gomes et al. (2008)	Talamanca Mountains, southern Costa Rica	Anthropogenic disturbances quantified by measuring girth of tress with dbh > 10 cm, total tree height and height of first major branching since primary trees have first major branch above half their height, whereby secondary trees have that below half height. The percentage ground cover of leaf litter, bare soil, dead material, grass and ground vegetation recorded to estimate to nearest 5%.

Table 2.1 continued

4.	Devictor et al. (2008)	France	Habitat disturbance measured by using TERUTI, an independent landscape survey based upon a systematic grid made of 15500 2 X 2 km squares on land use development throughout space and time.
5.	Zaccarelli, et al. (2008)	Apulia, southern Italy	Normalised Difference Vegetation Index (NDVI) is applied to differentiate disturbances between disturbed and undisturbed areas for Apulia region. Proportions of the disturbances estimated using standardised bi-temporal change detection procedure, based on values obtained from NDVI.
6.	Battisti v Fanelli (2016)	Latium region, central Italy	Hemeroby, an indicator measuring degree of disturbances applied, based on point scores, whereby higher score, more disturbed.
7,	Sagar et al. (2003)	Vindhyan hill ranges, India	100 subplots of 10 m ² workable quadrat in each hectare (100 x 100 m). All trees within quadrats counted and identified individually and put into three categories: pioneers such as <i>Macaranga</i> sp., planted trees, such as fruit trees and rubber trees.
8.	Shahabuddin & Kumar (2006)	Sariska Tiger Reserve, India	Indicators of disturbance were biomass extraction in designated plots.

Table 2.1 continued

		1. Proportion of trees showing signs of lopping (scale 0–4, of which 0 is minimum and 4 is maximum) 2. Average scale of lopping 3. Number of human trails traversing plot 4. Number of piles of livestock dung Disturbance index obtained from adding maximum value from indicators. Larger of the value is, more disturbed area is.
9.	Li et al. (2012)	Wuhan, central China Understorey species between two areas with different density of human population. Diversity of understorey species recorded in suburban areas higher than of urban areas. Shrub and layers significantly affected by disturbances caused by visitors and flow rate. Non-native herb species tend to increase in an urban area, with high anthropogenic disturbances, whereby wood species likely to be promoted in a suburban area with low disturbances.

Table 2.1 continued

		10 m ² workable quadrat used. Trees within quadrat counted and identified individually and put into three categories, pioneers, such as <i>Macaranga</i> sp., planted trees, such as fruit trees and rubber trees.
10.	Lee et al. (2001)	Singapore and Johor, Malaysia
		Forest types surrounded by different land-uses, with varying degrees of pre-known anthropogenic disturbance.
		Environmental variables include canopy cover, leaf litter depth, and density of trees with dbh (above 2 cm), mean and standard deviation of temperature, humidity and light intensity.
		Variables suggested being correlated to species richness and abundance of bee species at different forest types.
11.	Peh et al. (2005)	Peninsular Malaysia
		Disturbance evaluated on logging at least 30 years ago, small forests have open gaps, forest overgrown with pioneer plant species and public recreational purposes.
12.	Schreven, (2013)	Sebangau catchment, central Kalimantan, Indonesia
		Richness of ant species highest in an interior forest, followed by spots near forest edges and lowest at spots located in forest gaps
		Similarities in ant species highest between interior of forests, and between gaps, high between interior and forest edges; lowest between edges and gaps.

Table 2.1 continued

13.	Bryan et al. (2013)	Borneo	30 m resolution optical images and Carnegie Landsat Analysis System used to map forest cover and logging roads.
14.	Gaveau et al. (2014)	Borneo	Length of logging roads detected using LANDSAT MSS images as measure of disturbances due to logging.

2.1.3 Research Question, Objectives and Hypotheses

Disturbances are significantly correlated with human presence, but anthropogenic disturbances are usually quantified only by vegetation types. For instance, primary forest and gazetted protected forest are assumed to have the least disturbance without ground truthing investigations (Zakaria, 2000; Peh et al., 2005; Gray et al., 2007; Cusack et al., 2015). The current study is an attempt to quantify anthropogenic disturbances in human modified landscape which served as microhabitat for small animals.

In the Pelagus region, the villages have an agreement with the logging companies that they should not log an area within 1,000 m from the village. This agreement did not prevent the local resident from exercising their rights over the land and they continue to cultivate the land within this 1,000 m perimeter. Beyond the 1,000 meters boundary, a different kind of disturbance (logging and effect of logged-over forests) would have taken place before this study took place. This could have an influence on the existence of disturbance variations that originate from human settlements.

The objectives of this chapter were

1. to quantify the anthropogenic disturbance at the sampling stations by using disturbance value index and,
2. to compare the degree of the disturbance among stations with different forest types.

2.2 Materials and Methods

2.2.1 Study Sites

Field sampling for this study was in the Pelagus area, Kapit Division. Ten replicate stations were selected (Figure 2.1), three stations were behind human resettlements, namely Nanga Benin (N 2°11.584', E 113°07.086'), Nanga Pelagus (N 2°10.235', E 113°03.292') and Nanga Peraran (N 2°09.913', E 113°04.459'), and one station was located in Pelagus National Park, which was gazetted in February 2009. The national park sampling station was at least 2 km from the other stations. The total population at Ng. Benin, Ng. Pelagus and Ng. Peraran were approximately 100, 250 and 50, respectively, during the sampling periods, indicating high possibility of human presence in forested areas as all stations are accessible by the existing undulating and ascending jungle trails.

The main reason for selecting these stations was the presence of different types of habitat resulting from past and current anthropogenic activities. Shifting cultivation has been a traditional farming practice that was handed down from the ancestors to the present generation. The combination of the land use change and distance from the longhouses is expected to result in differences in the degree of disturbance.

Planted vegetation at the forest areas behind the settlements is also evidence of their activities. Vegetables such as *Gnetum gnemon* ('Daun Sabong') and *Manihot esculenta* ('Daun Ubi') are usually found often in the area within 100 metre from longhouses. *G. gnemon* was also seen as far as 500 m from the longhouse in certain forested areas due to the ownership of the land among the villagers. Other planted trees sighted include *Havea brasiliensis* (rubber tree), and several of fruit trees, such as *Durio*

spp. (Durian), *Nephelium* spp. (Rambutan), *Canarium odontophyllum* (Dabai), *Baccaurea motleyana* (Rampai) and *Garcinia mangostana* (mangostene).

Four forests or habitat types were identified from 10 stations in this study, namely secondary forest, logged-over forest, agroforest and primary forest. Each forest or habitat type is briefly described in Table 2.2. Table 2.3 shows topographical characteristics and forest type of all 10 stations at 100 m were near a river, which the settlement were named after (for example, Nanga Benin was situated next to Sungai Benin), station at 500 m were half-way ascending, whereby 1,000 m were at the highest altitude among all stations.

Abbreviations of these stations and forest types throughout the thesis include Pelagus National Park is PNP; Nanga Pelagus 100 m is PL100, 500 m is PL 500, 1000 m is PL1000; Nanga Benin 100m is B100, 500 m is B500, 1000 m is B1000; Nanga Peraran 100 m is PR100, 500 m is PR 500 and 1000 m is PR 1000; primary forest is PF, agroforest is AF, secondary forest is SF and logged-over forest is LF.

Researchers during samplings were divided into groups. A group of two members and a local was assigned at each station. This prevents unnecessary disturbance caused by researchers' continuous walking between stations. Presence of researchers was thus considered minimum and constant at all sites.



Figure 2.1: The sampling stations in Pelagus, Kapit

Table 2.2: Description of forest types (adopted from Pang et al., 2017)

No.	Forest type	Characteristic
1	Secondary forest (SF)	Trees generally < 20 m high, diameter at breast height of most trees under 30 cm, vegetative cover dense and <i>Macaranga</i> trees abundant.
2	Logged-over forest (LF)	Sign of recent logging, including skid trails for transporting log. Large trees occasionally emerging from surrounding canopy of smaller trees and large canopy gaps with regenerating vegetative cover.
3	Agroforest (AF)	Planted fruit trees frequently encountered and usually close to human settlements.
4	Primary forest (PF)	Abundant emergent trees, diameter at breast height usually > 50 cm. Relatively clear understorey and dipterocarp trees are common.

Table 2.3: Parameters comparison among stations at selected stations in the current study.

	PNP	PL100	PL500	PL1000	B100	B500	B1000	PR100	PR500	PR1000
Distance away from settlements (metres)	-	100	500	1000	100	500	1000	100	500	1000
Altitude (average in meters)	118.54	23.27	86.87	156.87	39.73	57.30	116.03	55.07	105.77	226.88
Vegetation type	PF	AF	SF	SF	AF	AF	SF	AF	SF	LF

2.2.2 Assessment of Human Disturbance Level

The scale system used in Shahabuddin and Kumar (2006) and Battisti and Fanelli (2016) was adopted and modified in the current study. The parameters used in the environmental assessment for investigating the degree of disturbances were divided into two components, human and plant, as shown in the Appendix 1. The former was a measure from the sighting on human and dogs or cats at each station while the latter was conducted within the 10 m² quadrat. Table 2.4 shows the methods of collecting the parameters and its ranking system, which referred as the disturbance index in this study.

2.2.2.1 Human Component

Humans are mobile. They utilise the forest commonly for resource harvesting, shifting cultivation and hunting. Regular visiting of the local to the forested area for collection of forest product or to maintain their farm or harvest what was planted are part of the attributes that are considered under the human component in this study.

The greater the number of locals seen in the sampling location per day, the more disturbed the area is expected to be. Similarly, their pets, such as dogs and cats, also hunt small animals, including birds for food in the surrounding forested area and ground-dwelling birds, such as babblers are particularly vulnerable to this threat. All human beings, cats and dogs encountered at the sampling location during the sampling duration were recorded and ranked. It was ranked 5 when there were 10 or more persons, ranked 4, when nine and 10 persons, ranked 3 six to eight people, ranked 2 when three to five persons were counted and ranked 1 when two person or less were encountered at the location (Table 2.4). The assumptions applied here was the efforts of the researcher is

constant and the count of human and their pets visiting to forest are independent from researcher presence.

2.2.2.2 Plant Component

The workable unit of the quadrat used in this study was 10 m² (Sagar et al., 2003; Li et al., 2012) to be adopted in the current study due to logistics and the topography of the sampling site. They are hilly. Three 10 m² quadrats were established at each station.

The presence of pioneer tree species such as *Macaranga* sp. and *Dillenia* sp. indicates that the area has previously been cleared (Goodale et al., 2014). Additionally, a disturbed area is likely to promote the growth of non-native plant species, particularly those whose seeds are air-borne and able to grow easily in a new environment. The more intense the disturbance is, the more heterogenous the habitat (Belote et al., 2008). Presence of planted trees (fruit frees, rubber and palm trees) also imply disturbance, because the locals were not only there when they planted the trees, but likely to visit the plot to harvest the fruits and palms or tap the rubber. The proportion of the combined pioneers, such as *Macaranga* spp. and *Dillenia* spp. (Shahabuddin & Kumar, 2006; Li et al., 2012) and planted trees at each plot was obtained by dividing their combined total by the total number of trees counted in the plot. The higher proportion of the combination is, the higher the ranking is, indicating that the area is more disturbed.

All trees within the quadrats were counted, identified and the diameter at breast height (dbh) (de Jesus et al., 2018) measured, using a dbh tape. Measured trees were categorised according to their dbh, as follows: < 15, 15.1–25, 25.1–35, 35.1–45 and > 45 cm (Table 2.4). Trees that have dbh > 45 cm are eligible to be logged. In terms of disturbance, the smaller and younger tree is given a higher disturbance ranking, because it

indicates the forest is recently disturbed. The number of trees in each category was divided by the total number of trees counted, the proportion (P) in the plot was then multiplied by its ranking (R) to get the values (R x P). Values of R x P from each station were then added up. The greater the value the more disturbed the area.

Canopy cover is commonly used to define the disturbance in an area (Goodale et al., 2014, de Jesus et al., 2018). The percentage of canopy cover was counted using a spherical densitometer. It was then ranked at 1 if the canopy cover is 100–80.1%, at 2 if it is 80–60.1%, at 3 if 60–40.1%, at 4 if 40–20.1% and at 5 if 20–0% as shown in Table 2.4 (Püttker et al., 2008).

Leaf litter could also provide informative indicator on human disturbance (de Jesus et al., 2018), as the accumulation of fallen leaves on forest ground explain how often locals visit the area. The measurement of leaf litter depth was taken at nine random points within plot. The depths of leaf litter were measured by vertically inserting a ruler until it touched the substrate. Areas with thick litter depth indicate fewer visitors to the area, thus is less disturbed. It ranks as 5 if the depth measurement is from 0–4.9 cm, ranks 4 when it is measured from 5–9.9 cm, ranks 3, from 10–14.9 cm, ranks 2 from 15–19.9 cm and ranks 1 when the thickness is higher than 20 cm (Table 2.4).

2.2.3 Statistical Analysis

2.2.3.1 Level of Disturbances

The disturbance index obtained from the accumulation of the rankings were then tested by Kruskal Wallis test in order to compare the components at different forest types. The components include (i) number of human and pet (ii) the number of pioneer and planted trees combined (iii) the R x P values (iv) percentage of canopy covers and (v) the

depth of leaf litter. The disturbance index is the collective disturbance ranking from above-mentioned components (i) until (v).

Kruskal-Wallis test was auto-calculated in Paleontological Statistics Software Package for Education and Data Analysis (PAST), version 3.23 (2013) (Hammer et al., 2011). This test was used as it also allows comparison between more than two samples, and the data in the current study are relatively small and not normally distributed.

Table 2.4: Selected covariates used in environmental assessment of disturbance modelling and the ranking system adopted.

Variables	Methods	Indicative measures				
		Ranking				
		1	2	3	4	5
Human component						
1. Total number of humans *	By sighting or encounter. Number of humans recorded	0 – 2	3 – 5	6 - 8	9 - 10	>10
2. Total number of pets *	Same as above	0 – 2	3 – 5	6 - 8	9 - 10	>10
Plant component						
1. The proportion of pioneer/planted species of trees, %	Pioneer species (<i>Macaranga</i>), and planted tree species (rubber, fruit trees) enumerated	0 – 20	20.1 – 40	40.1 – 60	60.1 – 80	80.1 - 100
2. Diameter at breast height, cm	By using diameter tape	>45	35.1 – 45	25.1 - 35	15.1 - 25	<15
3. Canopy, %	By using spherical densitometer	100.0 – 80.1	80.0 – 60.1	60.0 – 50.1	40.0 – 20.1	20.0 – 0
4. Leaf litter depth, cm	By using a ruler. Mean value of measurements taken as ruler was put straight upright on ground, penetrating leaf litter	>20	19.9 – 15	14.9 - 10	9.9 - 5	4.9 - 0

* Assuming that number of humans and pets passing by at time of survey is representative of time when researchers are absent.

2.3 Results

2.3.1 Human Component

Of all three sampled human settlements, the population was highest at Ng. Pelagus, followed by Ng. Benin and the least were at Ng. Peraran. Planting of pepper and collecting forest produce were commonly seen at the forest near the longhouses at Ng. Pelagus, compared to the other two.

A total of 33 counts of human and 31 counts of dogs and cats were obtained at different stations throughout the study (Table 2.5). This table shows that human and pet presence were greater and disturbance ranking higher at the stations closer to human settlement than those that are further away, and villagers tend to have activities in the area closer to settlements.

Ladies carrying baskets with accompanying dogs from the longhouses of Ng. Benin and Ng. Pelagus were seen harvesting forest produce. A man and a lady were also seen once walking by and claiming that they were just returning to the longhouse after working on their paddy farm. A group of five young men were seen at B1000 carrying shot gun and heading back to longhouses from hunting. Few people from the longhouse at Ng. Peraran were seen at the sampling area. Most villagers had left their home to work in the Kapit or Sibu town. Their lands are mainly abandoned, as senior citizens are not keen to do planting in the area. The logging track behind the longhouse at Ng. Peraran was claimed for construction of a link road, which would allow the locals access to Kapit town.

2.3.2 Plant Component

Of all stations, B1000 had the highest count of trees from three plots combined (94 trees), followed by 57 from both PNP and PL500. B100 had the least tree count of 18 (Table 2.6). Pioneer tree species such as *Macaranga* sp. and *Dillenia* sp., and planted trees like rubber tree, durian tree, and others were recorded separately, and their proportion over total number of trees within the quadrat was done thereafter. PL500 had the greatest number (47) and thus also had the highest percentage (82.46%) of pioneer and planted trees. Both PNP and PR100 had the least pioneer tree, eight individuals each, but the proportion wise, PNP recorded the lowest among all stations.

The diameter at breast height (dbh) of all trees in the plot was measured, recorded and grouped into six categories, as shown in Table 2.7. Most trees have relatively small dbh ranging from 5.1-15 cm. Trees of this size were found at most stations, except B500, PL500, PR500 and PL1000. Big trees with dbh 35 cm and above are generally few, even at PNP, < 10 individuals at all stations, except at PL500.

The disturbance ranking based on the tree counts, $R \times P$ where R is the ranking while P is the proportion of pioneer and planted trees, were shown in Table 2.8, indicating that disturbance ranking was the highest in PR100 (4.52) followed by PNP (4.45), B1000 (4.44), PL1000 (4.30) and PR1000 (4.24). The remaining stations PL1000, PL100, B500, PL500 and B100 were ranked relatively lower, at disturbance ranking of 3.97, 3.87, 3.42, 3.38 and 1.26, respectively.

Table 2.5: Total encounter frequency of human and pets at stations. PNP is Pelagus National Park, PL is Ng. Pelagus, B is Ng. Benin, PR is Ng. Peraran.

	PNP	PL100	PL500	PL1000	B100	B500	B1000	PR100	PR500	PR1000
Human encounters	0	11	2	0	10	0	5	4	0	2
Ranking	1	5	1	1	5	1	2	4	1	3
Animal encounters	0	12	2	0	13	0	2	0	0	2
Ranking	1	5	1	1	5	1	1	1	1	1

Table 2.6: Proportions of pioneer and planted trees recorded within fix-sized quadrates at each sampling station, Pelagus.

Station	PNP	PL100	PL500	PL1000	B100	B500	B1000	PR100	PR500	PR1000
Pioneer and planted trees	8	5	17	12	13	47	16	8	12	12
All trees	57	18	40	94	41	57	40	21	27	35
Proportion (%)	14.04	27.78	42.5	12.77	31.71	82.46	40	38.1	44.45	34.29
Ranking	1	2	3	1	2	5	2	2	3	2

Table 2.7: Count of pioneer and planted trees and proportion of count of total trees found in quadrat in each station.

DBH (cm)	PNP		PL100		PL500		PL1000		B100		B500		B1000		PR100		PR500		PR1000	
	TC	P	TC	P	TC	P	TC	P	TC	P	TC	P	TC	P	TC	P	TC	P	TC	P
< 5	15	0.25	1	0.02	0	0	13	0.27	0	0	6	0.16	14	0.15	8	0.32	13	0.38	0	0
5.1-15	31	0.53	23	0.52	16	0.28	11	0.22	8	0.44	4	0.11	52	0.55	10	0.4	8	0.24	26	0.62
15.1-25	5	0.09	5	0.11	17	0.29	11	0.22	2	0.11	12	0.32	11	0.12	3	0.12	4	0.12	8	0.19
25.1-35	3	0.05	6	0.14	9	0.16	5	0.1	2	0.11	5	0.13	10	0.11	3	0.12	6	0.18	4	0.1
35.1-45	3	0.05	4	0.09	5	0.09	5	0.1	3	0.17	6	0.16	6	0.06	1	0.04	2	0.06	2	0.05
> 45	2	0.03	5	0.11	11	0.19	4	0.08	3	0.17	5	0.13	1	0.01	0	0	1	0.03	2	0.05

Table 2.8: Disturbance ranking of all sampling stations based on different DBH categories and the proportion of pioneer and planted trees within the quadrats. R is disturbance ranking. P is proportion of pioneer and planted trees from Table 2.7.

DBH (cm)	R	PNP	PL100	PL500	PL1000	B100	B500	B1000	PR100	PR500	PR1000
		R x P	R x P	R x P	R x P	R x P	R x P	R x P	R x P	R x P	R x P
< 5	5	1.25	0.11	0	1.33	0	0.79	0.74	1.6	1.91	0
5.1-15	5	2.63	2.61	1.38	1.12	1.17	0.53	2.77	2	1.18	3.1
15.1-25	4	0.34	0.45	1.17	0.9	0.04	1.26	0.47	0.48	0.47	0.76
25.1-35	3	0.15	0.41	0.47	0.31	0.02	0.39	0.32	0.36	0.53	0.29
35.1-45	2	0.1	0.18	0.17	0.2	0.02	0.32	0.13	0.08	0.12	0.1
> 45	1	0.03	0.11	0.19	0.08	0.01	0.13	0.01	0	0.03	0.05
Total		4.45	3.87	3.38	3.94	1.26	3.42	4.44	4.52	4.24	4.30

PL500 had the densest canopy cover on average amongst all stations, followed by PL100 and B1000. Canopy covers in PNP was less dense. The forested areas of Ng. Peraran are relatively the least dense (Figure 2.2). Despite the varieties of the canopy covers at all stations, they were all above 80 %, which is ranked at 1.

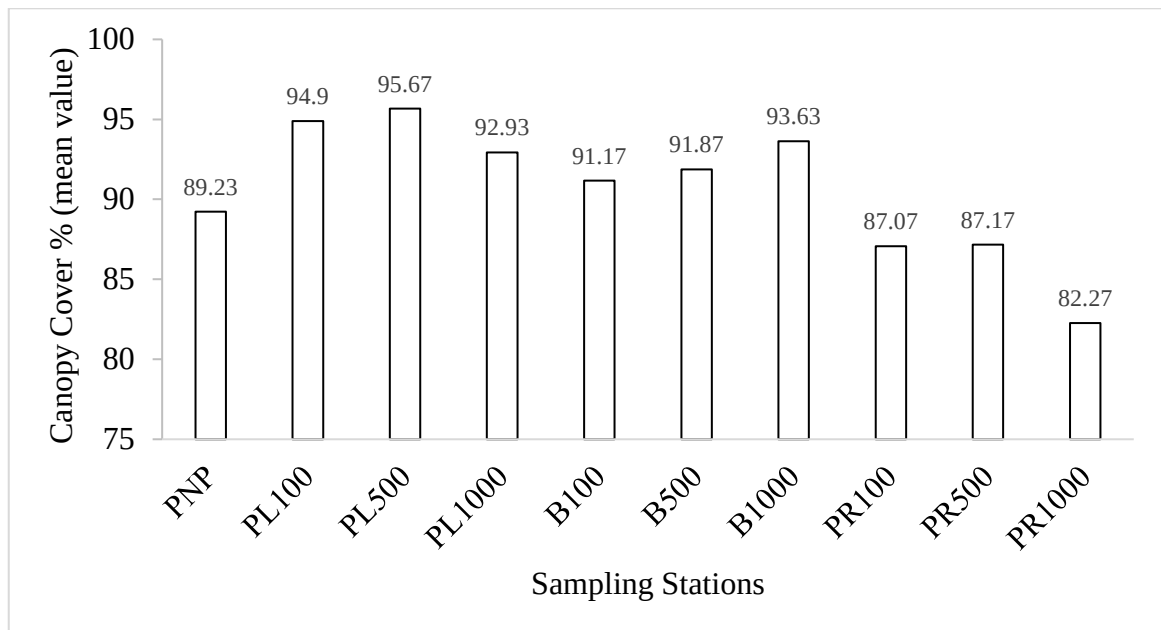


Figure 2.2: The canopy covers of each sampling station.

Leaf litter depth (lld) was measured randomly at nine points for each sampling station (Table 2.9). Overall, PR1000 had the shallowest leaf litter, with a mean value of only 0.6 cm, thus is ranked 5 (most disturbed) in the disturbance ranking system. B1000 had the deepest leaf litter, with a mean value of 9.3 m, and is ranked at 4.

Table 2.10 below listed the parameters which are potential attributes of the human and plant component. The human component affects wildlife directly through hunting, whereby hunters and their carnivorous pets both kill and scare wildlife. The plant component affects wildlife indirectly by changing the characteristics of their habitat. Direct

disturbance has traumatic but shorter-term effect while indirect disturbance causes extensive effect in the long term.

The cumulative disturbance indices suggest that the PL100 is the most disturbed, while PL1000 m is the least disturbed amongst all stations (Table 2.10). Four stations were in secondary forests (PL500, PL1000, B1000 and PR500) and another four (PL100, B100, B500 and PR1000) were in agroforest. Kruskal-Wallis test showed agroforests to be significantly more disturbed than secondary forests ($p = 0.021$).

Table 2.9: The depth of leaf litter at stations in Pelagus, Kapit.

Point	PNP	PL100	PL500	PL1000	B100	B500	B1000	PR100	PR500	PR1000
Point 1	0	2	1	5	1.5	2	3	2	1	0
Point 2	3	2	1	5	2	4	4	4	2	0.2
Point 3	5	2	2	7	2.5	5	4	5	2	0.3
Point 4	5.5	2	4	8	3	5	5	5	3	0.5
Point 5	6.5	2	5	9	5	6	5	5	7.5	0.5
Point 6	9	4	5	9	5	7	5	7	8	0.5
Point 7	10	4	5	10	5.5	12	6	9	10	0.7
Point 8	10	6	5	13	7	12	6.5	10	11	1
Point 9	14	7	6	18	8	12	8	10	13.5	1.3
Mean depth	7	3.4	3.8	9.3	4.4	7.2	5.2	6.3	6.4	0.6
Ranking	4	5	5	4	5	4	4	4	4	5

Table 2.10: Disturbance index of each sampling station in Pelagus.

	PNP	PL100	PL500	PL1000	B100	B500	B1000	PR100	PR500	PR1000
	PF	AF	SF	SF	AF	AF	SF	AF	SF	LF
A: Human component										
Total # of human	1	5	1	1	5	1	2	4	1	3
Total # of pet	1	5	1	1	5	1	1	1	1	1
B: Plant component										
Proportion of pioneer / planted sp. of trees	1	2	3	1	2	5	2	2	3	2
Dbh ranking*	4.45	3.87	3.38	3.94	1.26	3.42	4.44	4.52	4.24	4.3
Canopy	1	1	1	1	1	1	1	1	1	1
Leaf litter depth	4	5	5	4	5	4	4	4	4	5
Cumulative rank	12.45	21.87	14.38	11.94	19.26	15.42	14.44	16.52	14.24	16.3

* refer values from Table 2.8

2.4 Discussion

Instead of quantifying the anthropogenic disturbance level by ground-truthing fieldwork, previous studies often ascribe primary forests as undisturbed and non-primary forest or forest degraded by logging and cultivation as disturbed forest (e.g., Peh et al., 2005; Peres et al., 2006; Posa & Sodhi, 2006; Shahabuddin & Kumar, 2006; Gomes et al., 2008). Some studies utilised satellite images and defined disturbance based on the percentage of forest covers and logging tracks (Devictor et al., 2008; Zaccarelli et al., 2008; Sigel et al., 2010; Gaveau et al., 2014). In this chapter, anthropogenic disturbances were quantified based on the presence of human and their pets as well as evidence of their activities which impacted the environment surrounding the longhouse.

Sampling stations that are closest to the longhouses have the highest disturbance index. Agroforest in PL100, B100 and PR100 are ranked the highest in terms of disturbance index, possibly because they are closer to human settlements. The utilisation of the land for example for slash-and-burn cultivation (Tisen, 2001) was comparatively heavier in areas closer to the longhouses. The on-off trail trampling (Shahabuddin & Kumar, 2006; Li et al., 2012) is worse with higher number of human and pets passing by. Activities such as fruits collection and forest produce harvesting were likely to be concentrated in areas nearest to the longhouses (Tisen, 2001; Sanggin et al., 2016). It is also an area where villagers would pass through when they go further into the forest. Few groups of villagers with dogs were seen carrying out activities such as hunting and harvesting forest produce and passing via 100 m sampling station at both Ng. Pelagus and Ng. Benin. It is also due to a higher population in the longhouses at Ng. Pelagus and Ng. Benin than Ng. Peraran.

Food demand is believed higher in both Ng. Benin and Ng. Pelagus due to the greater population from longhouses. B100 and PL100 have vegetables such as *Sauropus androgynus* ('Cangkuk Manis'), *Solanum ferox* ('Terong Asam') and fruit trees such as *Musa* sp. (banana) planted in those stations. In addition, a tractor was also seen clearing land in an area near PL100. This land was claimed by a family from the longhouse for planting pepper. It was easy and convenient for the local people (adults and teenagers), and their pets to go the forested areas behind their longhouse because they are familiar with the land. There are greater number of planted trees at Ng. Benin and Ng. Pelagus with higher human population. Planted trees with 35 cm dbh and above recorded B100 and PL100 were *Durio* sp., *Mangifera* sp., *Artocarpus* sp. and *Calophyllum* sp.

Secondary forests in PR500, PL500 and B1000 have similar cumulative disturbance ranking, ranging from 14.38 to 14.44, while PL1000 which is also located in secondary forest is ranked the lowest with cumulative disturbance ranking of 11.94. This station is said to be abandoned after the selective logging has ceased and with no encroachment (Win, a resident of Rumah Bujah, Ng. Pelagus, pers. comm.). Many people, including landowner, have also migrated to the city (e.g., to Sibu) for a steady wage occupation and thus left the land and rubber trees unattended (Ichikawa, 2007, Sabut per. comm.)

Logged-over forest at PR1000 was heavily impacted by logging. Despite it being a distant station, PR1000 had an active human presence. It is accessible via the skid trail used by a logging company. The skid trail also becomes a convenient route for hunting, as in many other places (Bennett & Gumal, 2001). Additionally, the State Government proposed linking Pelagus with Kapit town, by repairing and constructing a road from the

existing logging skid trail at PR1000, with Ng. Peraran as the connecting point. When this study was conducted, several authorised land surveyors were encountered.

The supposedly primary forest in PNP has no adjacent human settlements nor presence of relevant authority and visitors, yet the area was found to be more disturbed than PL1000. This could be due to impact from the Pelagus Resort including the former workers' quarters which were built close to the forest. Most of the workers of the resort were the residents from adjacent long houses. Existing trails are clearly visible, and ropes were installed to guide the resort guests to walk the forest trail. This creates a greater accessibility for local people from adjacent longhouses to the forest trail for hunting and forest produce collection. Thus recovery to the original status might be difficult (Visco et al., 2015), despite the resort being no longer operational.

The number of large trees (with dbh 35 cm and above) in the primary forest (PNP) was less than other forested areas behind the human settlement, except Ng. Peraran. It could probably be due to extraction of large trees for the construction of the resort which was undertaken before the area was gazetted as Pelagus National Park. The large trees close to human settlement were planted trees by the community when they first settled in the area, and include such trees as Engkabang (*Shorea* sp.) and other fruit trees.

The result obtained from another comparison using Kruskal-Wallis test showed that agroforest was significantly more disturbed than secondary forests. Agroforests are closer to human settlements and has higher number of planted trees that the villagers depended on their livelihood, for example, by collecting fruits during season or tap rubber when the price of the rubber is high (Sagar et al., 2003, Peh et al., 2005) than secondary forests in

the context of this study. The higher presence of human and domestic animals in adjacent agroforest also contributed to its degree of disturbance.

2.5 Conclusion

Anthropogenic disturbances in all sampling stations were quantified based on the human and plant components in this study. The stations with the lowest disturbance index was PL1000 while the highest was PL100, suggesting that the closer an area is to human settlements the more disturbed it is.

Stations located at 100 m from the longhouse were occupied by agroforest while stations further away were occupied by secondary forest. Agroforest have the highest disturbance ranking values, significantly higher than that of secondary forest.

Quantifying the disturbance shall be carried out ground-truthing than compared based on the forest types. The levels of anthropogenic disturbance of areas occupied by the same forest types could be varied.

CHAPTER 3

THE DISTRIBUTION AND OCCUPANCY OF BABBLERS IN DISTURBED FORESTS IN PELAGUS

3.1 Introduction

Previous studies report that many wildlife, including birds, respond negatively to disturbance (Barlow et al., 2006; Shahabuddin and Kumar, 2006), while some do not (Edwards et al., 2011; Srinivasan et al., 2015). For instance, the density, biomass and the distribution of food resources in the forest could be altered as a result of disturbances (Walker & del Moral, 2003; Barlow et al., 2006).

Chapter 2 shows that disturbance variations from different forest types in Pelagus. A heavily disturbed area resulting from intensive human presence and activities such as the agroforest where villagers are still actively utilising the land. An abandoned and distant secondary forest is the least disturbed as presence of human is low.

Distance from the road was reported to be a factor that affected distribution and relative abundance of mammals in Kubah National Park, western Sarawak (Mohd-Azlan et al., 2018). Forest types, particularly logged forest, are reported adversely affect the mostly ground-dwelling birds species (Peh et al., 2005). This could be due to the loss of food resources, especially insects, where rate of decomposition of leaf litter were reported to be decreased in logged forest (Yeong et al., 2016). Accessibility of an area after logging could reduce habitat of ground-dwelling invertebrates, as leaf litter could be trampled by humans (Li et al., 2012), and also small-bodied size birds are vulnerable to predators, domestic cats and dogs if the areas close to human settlement, which will attack them (Hong & Mohd-Azlan, 2018).

Babbler occurrences and their count are hypothesized to be influenced by different disturbance levels. Chapman and Reich (2007) reported that bird assemblages change along the areas with different gradient that was measured in the canopy structure and land use; grassland to savannah to forests. Chan et al. (2008) demonstrate that the abundance and composition of bird assemblages varied between two areas, at different distances from the stream. Riparian zone was 30 m away from the stream, while the secondary forest that was 100–250 m away and further inland. Avian insectivores were in greater numbers at riparian zones compared to an inland secondary forest.

Birds have long been used as a reliable and effective indicator of environmental change. They are good representative (Mekonen, 2017), especially on Borneo, being both speciose and abundant, and are a widely studied, subject and easily understood. For instance, tropical understorey insectivorous birds are reported to be highly specialised in their habitat use and their mobility restricted, by forest gaps (Stouffer & Bierregaard, 1995). They are also responsive to environmental change or in other words, tractable (Barlow et al., 2006). For example, tropical insectivorous birds, such as *Turdoides striata* (Jungle Babbler) and *Zosterops palpebrosa* (Oriental White-eye) were reported to be adversely affected by anthropogenic disturbances (Shahabuddin and Kumar, 2006; Posa and Sodhi, 2006), however, the effects of post-logging on the diversity of forest birds remain unclear (Zhao et al., 2013). Ease of collection is also another advantage making birds a good indicator (Costantini et al., 2016; Peh et al., 2006), alongside small mammals, insects and the aquatic fauna (Hamer et al., 2005; Sodhi et al., 2004).

Among the birds, the babblers (Timaliidae and Pellorniedae) were chosen for several reasons. They are relatively abundant, hence the greater chance of encounter or

being captured. Babblers are encountered mostly in the forest understorey (Barlow et al., 2006; Mansor et al., 2015) and as a result, they are a suitable representative of forest birds, especially those inhabiting the understorey or are insectivorous. Additionally, they can adapt to various types of habitats, in human-disturbed areas or otherwise.

This chapter investigates 1) the responses of babblers to disturbances, mainly through their spatial distributions in the forested areas, and 2) the coexistence of understorey babblers with other sympatric species within avian assemblages.

3.1.1 Babblers Diversity in Degraded and Undegraded Forest

A total of 674 species of birds are known to occur on Borneo (Lepage, 2018), including migratory and resident species. Their habitats ranged from the montane, primary, lowland, peat swamp, mangrove, secondary and logged forests. Babblers inhabit various habitats and niches in Borneo, such as the highland, limestone, secondary and peatswamp forest (Lambert, 1992; Mansor et al., 2011; Amit et al., 2014; Ramji et al., 2016). The widespread occurrence of babblers (*Macronous* spp. and *Trichastoma* spp.) is probably due to their resilience and ability to adapt to different environments and disturbance or in coexistence with other species. Table 3.1 shows the number of babblers captured at various localities in the forests of Peninsular Malaysia and in Sarawak.

Table 3.1: Percentage of babblers captured from various habitats in Peninsular Malaysia and Sarawak.

No.	Citation	Localities	Forest types	Total number of bird species (% of babbler)
1	Zakaria (2000)	Sungai Lalang Forest Reserve, Selangor.	Logged forest	55 (21%)
2	Zakaria et al. (2005)		5-year-old logged forest	9 (20%)
			10-year-old logged forest	28 (28%)
3	Peh et al. (2005)	Bekok Johor	Primary forest	157 (15%)
		Belumut, Johor	Primary forest	148 (15%)
4	Ghasemi & Zakaria (2008)	Ayer Hitam Forest Reserve, Selangor	Secondary forest	38 (8%)
5	Razak et al., (2015)	Tanjung Datu National Park, Sarawak	Lowland mixed dipterocarp forest	39 (15%)
6	Ramji et al. (2016)	Kota Samarahan, Sarawak	Peat swamp	87 (12%)
7	Pang et al. (2017)	Gunung Penrissen	Logged-over hill dipterocarp forest	178 (13%)
8	Burner et al. (2018)	Mt. Topap Oso	Shifting agriculture and primary forest	155 (13%)
		Gunung Pueh and Gunung Mulu	Selective logged-over forest and primary forest	151 (13%) & 35 (6%)

Table 3.1 continued

9	Attiqqah et al. (2018)	Long Banga, Ulu Baram, Sarawak	Primary forest	38 (37%)
		Long Kesseh, Ulu Baram, Sarawak	Secondary forest	50 (18%)

Primary forest may still be the favourable habitat for babblers, especially the Striped Wren-babbler that was only recorded in Long Banga and not from any other habitats mentioned in the table above. Nevertheless, babblers can thrive in a recovery forest as their population picks up in the logged forests as reported by Zakaria (2000) and Zakaria et al. (2008). In other habitats, occurrence of babbler in the community are likely stable, on the average 12%. As the mist-nets were set mostly at the level of 0.2–3 m from the ground in the forest understorey, mid-storey and canopy-level species were likely to be under-represented.

3.1.2 Babbler Response to Human Induced Disturbance

Babblers are reported to be sensitive to fragmentation of their habitat, decreasing in numbers after logging has taken place (Ghasemi & Zakaria, 2008; Yong, 2009). Yet, Styring et al. (2016) reported that the occurrence of seven sympatric babblers in five different habitats, namely continuous native forests, native forest fragments, mature plantations (over five years), young plantations and oil palms. The babblers included *Stachyris erythroptera* (Chestnut-winged Babbler), *S. rufifrons* (Rufous-fronted Babbler), *S. maculate* (Chestnut-rumped Babbler), *S. nigricollis* (Black-throated Babbler), *S. poliocephala* (Grey-headed Babbler), *Macronous ptilosus* (Fluffy-backed Tit Babbler), and *M. gularis* (Pin-striped Tit-Babbler). They occurred at most of these habitats, except oil

palm. This indicated that some babblers can survive in various forest types with different disturbance levels. Only the Chestnut-winged babbler was captured in oil palm plantation, which imply that the species tolerates a more disturbed habitat. The *M. borneensis* (Striped Tit-Babbler) was also found abundantly in disturbed habitats, such as oil palm plantations (Yong, 2009; Amit et al., 2015).

3.1.3 Foraging Pattern of Babblers

Diurnal birds mostly forage heavily in the mornings and secondarily in the afternoons (Bednekoff & Houston, 1994) because they need the energy in the morning after a night of fasting and to retain energy levels for the following night. In addition to the timing, birds which have similar food preferences from feeding guild (Poulin et al., 1994) exhibit similar foraging behaviour. For instance, the manoeuvre and foraging height in forest such as in the range of 0 – 10 m understory, aerial and canopy (Wielstra et al., 2011).

In this study, the mist-netted birds were grouped into feeding guilds according to Myers (2009) and Phillipps and Phillipps (2014) for Bornean birds (Table 3.2). The combination of two feeding guilds indicates that the birds shift their diets during shortage of preferred food in the forest. For instance, frugivore-insectivores implies that of the group of birds feed on fruits as an obligate, but occasionally prey on insect when fruits are scarce, and vice versa.

Table 3.2: Definition of avian feeding guilds (Pang et al., 2017).

Feeding guilds	Definitions
Insectivore	Feed exclusively on arthropods including insects.
Nectarivore	Feed exclusively on nectar of flowers.
Frugivore	Feed exclusively on fruits on tree or ground.
Granivore	Feed exclusively on grains or seeds from plant or on ground.
Frugivore-Insectivore	Feed primarily on fruit but shift to insects when fruit volume is low.
Carnivore-Insectivore	Feed primarily on small mammals, birds or fishes but shift to insects when former is low.
Insectivore-Frugivore	Feed primarily on insects but shift to fruits when insects are low.

3.1.4 Spatial Distribution of Birds

Stratification is a mechanism of co-existence within community to occupy spaces in confined area. Such distributions usually are associated with food (Chmel et al., 2016). Food resource partitioning is the divergence or adaptations of exploiting various resources upon the occurrence of overlapping similar resources in an interspecific community (Walter, 1991). Resource partitioning promotes coexistence of sympatric interspecies, which not only allows the usage of a variety resources but also reduces competition.

In mangrove patches located in the Darwin region of northern Australia, Mohd-Azlan et al. (2014) reported that foraging height of mangrove birds ranged from 0 to 18 m, except for bee-eaters, honey-eaters and flycatchers which were sighted foraging on insects and nectar in the tree canopy. The latter also used the sparse understorey to forage, in addition to snatching prey from above the canopy. In another study in a tropical mixed dry deciduous forest of Anaikatty hills, southern India, *Gallus sonneratii* (Grey Junglefowl) was found foraging at the ground level. Five species, such as *Acridotheres fuscus* (Jungle Myna), *Turdoides affinis* (Yellow-bellied Babbler), *T. striatus* (Jungle Babbler), *Pavo cristatus* (Indian Peafowl) and *Upupu epops* (Common Hoopoe) not only foraged at

ground level but also at higher sites (Thivyanathan, 2016). These studies demonstrate vertical stratifications within bird communities.

Kumar et al. (2009) reported that six groups of birds shared a tree at Nelapattu Bird Sanctuary, India, by occupying different branches and levels. Their positions on a tree, ranked from the top, are the *Anastomus oscitan* (Openbill storks), followed by *Threskiornis aethiopica* (White Ibis), *Egretta garzetta* (Small Egrets), *Ardea elba* (Large Egrets), *Ardeola grayii* (Heron) and *Phalacrocorax* sp. (Cormorants). Taking the bottom part of tree was the *Tachybaptus ruficollis* (Dab chicks), which was believed to be associated with waterweeds and wild grass. Having overlapped their niches in disturbed and undisturbed sites of La Malinche National Park, Tlaxcala, Mexico, *Sitta pygmaea* (Pygmy Nuthatches), *S. carolinensis* (White-breasted Nuthatches) and *Certhia americana* (Brown Creepers) were seen occupying their respective heights on the tree, on thin branches, thick branches and at the lower trunk (Lara et al., 2015). Interspecies birds with close phylogenetic relationships ecologically share niches.

Partitioning resources is known to minimise interspecific food competition. Calvi et al. (2008) reported that the observed ant-foraging birds such as *Gymnopithy slencaspis* (Bicolored Ant-bird), *Eucometis penicillata* (Grey-headed Tanagers), *Dendrocincla anabatina* (Tawny-winged Woodcreeper) and *Dendrocolaptes certhia* (Barred Woodpecker) in La Sirena Biological Station in Corcovado, Costa Rica were exhibiting various foraging manoeuvres. The perching at horizontal distribution, foraging height and foraging substrate varied significantly.

In lowland areas of the tropics, bird guilds are stratified vertically and spanned from the ground to the canopy. Seven avifauna families, namely, Cuckulidae, Capitonidae,

Eurylaimidae, Campephagidae, Chloropseidae, Dicruridae and Oriolidae are seldom captured in the understorey, as they utilise canopy space (Rahman, 2002). A majority of understory birds were found using the above-ground space 1.2 to 2.4 m in different forest types namely primary forest, logged-over forest, secondary forest, agroforest through Sarawak, Borneo (Pang et al., 2017). *Arachnothera longirostra* (Little spiderhunter), in particular was recorded to have a larger range above-ground, 0–3.6 m as the food resources of this species may be distributed wider vertically. Compared to other guilds, such as nectarivores and frugivores, insectivores utilise the space to the ground, 0–1.2 m above ground (Pang et al., 2017). Birds in other guilds are likely to stay far from the ground as their food resources were not close to ground. This behaviour shown by the birds promotes the coexistences among interspecific bird community.

Insectivores, such as babblers, occupy highly restricted microhabitats. Six babbler species were reported occurring in two different forest types, logged forest (LF) than unlogged forest (UF) in Ulu Segama Forest Reserve, Sabah. All babblers flew higher in UF, except the *Malacopteron affine* (Sooty-capped Babbler) which had a slightly higher foraging height in LF (Lambert, 1992). The highest of each babbler flew in unlogged forest was 9.26 m by *M. magnum* (Rufous-crowned Babbler); 5.80 m UF by *M. magnirostre* (Moustached Babbler), 5.70 m by *Stachyris erythroptera* (Chestnut-winged Babbler), 3.86 m by *Macronus ptilosus* (Fluffy-backed Tit-Babbler) and 2.63 m by the lowest flyer, *Trichastoma bicolor* (Ferruginous Babbler) which flew at 2.63 m. *Malacopteron affine* (Sooty-capped Babbler) had a slightly higher foraging height in UF than LF, which was 6.67 m and 6.29 m, respectively.

A recent study carried out in a mixed vegetation, comprising orchards, secondary forest, limestone forest and lowland dipterocarp forest located at Lenggong Valley, Perak. It compared the niches used by *Malacocincla abbotti* (Abbott's Babbler) and *S. erythroptera* (Chestnut-winged Babbler), the former found using the ground, and up to four metre off ground, while the latter did not use the ground area but showed a wider range from off-ground up to 12 m (Mansor et al., 2015). Another study by (Mansor & Ramli, 2017) showed an ecological division of nine babblers in four groups utilising different heights in the forest in Krau Wildlife Reserve. *Malacopteran magnum* (Rufous-winged Babbler) and *Stachyris maculata* (Chestnut-rumped Babbler) used mostly at 6–8 m; *M. cinerum* (Scaly-crowned Babbler) at 4–6 m; *S. nigricollis* (Black-throated Babbler), *S. erythroptera* (Chestnut-winged Babbler), *Pellorneum bicolor* (Ferruginous bicolor) and *S. nigriceps* (Grey-throated Babbler) at 2–4 m; and *P. malaccense* (Short-tailed Babbler) and *P. capistratum* (Black-capped Babbler). One may conclude that babblers partition their niches which would promote coexistence.

3.1.5 Temporal Distribution of Birds

Frugivorous birds and primates tended to migrate to secondary forests during low fruit abundance in primary forests. Movement of frugivores between different forests during different periods are in accordance to the availability of food resources has been widely documented (Buji et al., 2002; Kimura, 2003; Yoshikawa & Osada, 2015). Nevertheless, insectivores are unlikely to shift forest like frugivores do (Gleditsch et al., 2017), as the abundance of insect may not fluctuate. In addition, some would shift their diets from insects to fruits.

The composition of understorey insectivorous birds in the secondary Atlantic Forests of south-east Brasil accounted for 243 individuals of 15 species. Despite variation of annual rainfall being 1536 mm between the dry season (June and July 2006) and the wet one (January and February 2006), there was no marked temporal variation in the diversity of understorey insectivorous birds (de Carvalho Lima & Manhaes, 2017). The prey in that area were presumably enough to sustain the understorey bird community all year round.

The number of insectivorous birds, such as *Leiothrix argentauris* (Silver-eared Mesia), *Zosterops japonicus* (Japanese White-eye), *Minla cyanouroptera* (Blue-winged Minla), *Alcippe morrisonia* (Gray-checked Fulvetta), *Stachyris ruficeps* (Rufous-capped Babbler), *Orthotomus cucullatus* (Mountain Tailorbird) and *Parus major* (Great Tit), was reported higher in riparian zone of a secondary forest, especially during the wet season than the dry one in Hong Kong. This could be due to the availability of prey (both terrestrial and aquatic volant insects), such as the Ephemeroptera, which was 31% higher during the wet season (May – September 2006) than the dry one (December 2006 – March 2007) (Chan et al., 2008).

Ficedula narcissina (Narcissus Flycatcher) in a Japanese deciduous forest foraged at multiple level in the forest, following the change of prey abundance over time. From late May to the middle of June, they forage in the canopy. Foraging take place on the ground until late June. Later, they would fly back to the canopy until early July (Murakami, 2002).

To avoid competing for food resources in the same habitat, two sympatric species, *Acrocephalus melanopogon* (Moustached Warblers) and *A. Scirpaceus* (Reed Warblers) at a marshland in Spain breed at different times. The former had an incubation period of seven week earlier and the first catch of its fledge was six weeks before the corresponding

period of the latter. The changing of the stages makes both species have different requirement on diet, and thus reduce the diet overlap (Ceresa et al., 2016).

3.1.6 Research Questions, Objectives and Hypotheses

This chapter asks what bird species are present in the disturbed forests in Pelagus, and how many babbler species are present or absent in the said habitats. How do babblers respond to the disturbed forests with varying environmental covariates; which covariate is the most impactful to the babblers? In addition, how do sympatric babblers coexist spatially and temporally?

With various degrees of disturbances in a forested area, an issue arises as to how bird assemblages can be influenced. Will bird distribution be affected by the degree of disturbance? Would babbler assemblages and their occupancies at each station be affected by disturbance, or by the covariate (s) that contribute to the disturbance?

The objectives of this chapter were

- 1) to determine babbler composition and its proportion within overall understorey avian assemblages in all sampling stations;
- 2) to elucidate which disturbance covariate(s) affect babbler occupancy and probability of netting;
- 3) to investigate how interspecific tolerance, coexistence and partitioning (spatial effect) take place in a specious and sympatric babbler community, and
- 4) to determine temporal effect on babbler abundance over the study period.

This chapter's hypotheses including:

- 1) The diversity of babbler species in forests with different disturbances is not the same.
- 2) The disturbance covariates affect the occupancy and detection probability of babblers recorded in this study.

3.2 Materials and Methods

3.2.1 Study Sites

Surveys were conducted in the forested areas of all 10 stations mentioned in Chapter 2. Four stations are occupied by secondary forest and four by agroforest, one by primary forest and logged-over forest, respectively. Common features shared among the sites include 1) all were in the forested area within 1,000 m behind human settlements, 2) All stations were accessible via undulating existing trail, 3). All stations were covered by dense vegetation of grasses, ferns, shrubs and small trees up to about 2.5 m above ground, and above this by a relatively clear space until the main canopy. The distances, forest types with different tree compositions, disturbances attributed by various covariates were the characteristics that stations did not share. Sampling at three stations behind the longhouse was conducted concurrently in all trips.

3.2.2 Field Sampling

The conventional mist-netting method was used because of its effectiveness (Rahman, 2002; Barlow et al., 2006) especially for cryptic birds such as the *Stachyris poliocephala* (Grey-headed Babbler) that are hard to spot but can be captured by mist nets (Myers, 2009). All nets used in this study were made of fine back twine, has 3-shelves,

measured 9 m long and 2.5 m high and have 36 mm mesh-sized. The nets were opened for a duration of 12 hours, from 0630 to 1830 hours, for four days consecutive (48 hours in total). All captured birds were ringed, measured and weighed before being released. Bird identification was based on Robson, (2008); Myers (2009) and Phillipps and Phillipps (2014). The list was then after double-confirmed by referring to the updated checklist online on Avibase – the World Bird Database at (<http://avibase.bsc-eoc.org/checklist.jsp?region=BORandlist=howardmoore>).

3.2.2.1 Assessing Understorey Space Utilisation by Babblers

Horizontal space use was studied by deploying nets at distances of 100 m, 500 m and 1,000 m away from human settlements; and one station at the National Park which is more than 2000 m from each longhouse. Each station had eight points selected randomly where nets were deployed. Unproductive nets were relocated within the area of the station in order to maximise the capture rate.

Vertical space use data was determined by looking at the height of the shelves above-ground where birds captured in. For this purpose, conventional mist nets were modified by stacking one net upon each other by stitching the bottom line of the upper net to the top line of the lower net. This combined net extended up to the height 3.6 m above ground comprising a total of six shelves and numbered 1 (closest to the ground) to 6 (top-most shelf). Height of each shelf was 0.6 m. A small portion of each shelf was folded inward horizontally to form a long pocket to hold the birds when they flew into the nets. Telescopic aluminium poles were used to set up the nets. This modified set of net was hereby termed double-stacked mist-net. Shelf numbers were recorded specifically for every bird captured.

3.2.2.2 Assessing Temporal Effect

Sarawak experiences the Northeast Monsoons with the heaviest rainfall starting from November to March and Southwest Monsoons from June to September, which has lower rainfall. Two transition periods from April to May and October to November experience change of wind and bring occasional rain in (Source: Sarawak Department of Meteorology Malaysia, Sarawak branch).

For analysis of temporal effect, repeated samplings were conducted over a period of 12 months from December 2014 until November 2015. Over this period, all sampling stations were visited four times. The first period of sampling was conducted in December 2014 until January 2015, the second in March – April 2015, the third in August 2015 and the fourth in November 2015. In order to elucidate if the utilization of avian assemblages in the understory of the forest was consistent in a year, samplings were conducted repeatedly at the same locations of each station. Rainfall data were collected from Department of Meteorology, Malaysia, which had weather stations installed in Kapit town.

3.2.3 Statistical Analysis

Parameters measured on babblers responding to anthropogenic disturbances in the current study were species accumulation curve, species richness, abundance and occupancy of all species.

3.2.3.1 Species Accumulation Curve

Both species accumulation curves were obtained by using the package *vegan* (Oksanen et al., 2007) in R (R Core Team, 2018). Method chosen was exact (y-axis), which implies that the exact individual number of each species were used for the analysis, over total numbers of sites (x-axis). Another species accumulation curve which

investigated the total number of babbler species (y-axis) against the total sampling days was analysed also using the same package.

3.2.3.2 Proportion of Babblers' Species

All babbler species were analysed for capture rate and relative species abundance. They were calculated using the individual number (inclusive of recaptured individuals) and calculated in Microsoft Excel as follows:

$$\text{Capture rate} = \frac{\text{Total number of bird captured}}{\text{No. of nets} \times \text{No. of days} \times \text{No. hours deployed}}$$

$$\text{Relative species abundance} = \frac{\text{Total individuals of one species}}{\text{Total number of all species}}$$

Rank abundance curve or Whittaker plot was produced by using the relative species abundance in log to determine which species are common or rare in this study. The curve was produced in Microsoft Excel (2016).

3.2.3.3 Occupancy and Netting Probabilities

The probabilities of occupancy and the probability to capture the babblers by nets (also known as netting probability) of overall in this study were tested by using Bayesian analysis which deals with small samples (Baldwin & Fellingham, 2013) in R, package *jagsUI* (Kellner, 2018) with three iterations and 10,000 stimulation data. Occupancy model deals with the study of subjects that may not be detected but their occurrences were positive (Bailey & Adams, 2005).

3.2.3.4 Disturbance Effect

The test on which covariates affect the most on the occupancy and netting probability of each babbler was run in R, package *wiqid* (Meredith, 2019), with Akaike Information Criterion (AIC) formula, as shown below (Arnold, 2010).

$$AIC = 2 * (\text{No. of parameters}) - 2 * (\log \text{likelihood})$$

AIC values converted to AIC correction (AICc) which they are applied to determine the covariate(s) affects the diversity of babblers when sample sizes are relatively smaller (Mohd-Azlan et al., 2018). Covariates are the disturbance attributes tested in Chapter 2, and with addition of the distance, elevation and forest type. The lower AICc value is the more parsimonious the model or that attributes which affect the babblers; given that the differences between the lowest values is greater than 2 (the deviance square), otherwise, the model is not anymore parsimonious than another. AICc was used to determine which covariate of the human disturbances is the best to describe the occupancy and probability of netting of each study subject in this study (Arnold, 2010).

3.2.3.5 Diversity Indices

Diversity was quantified by Shannon Index, which is the most widely used index. It requires the individual number of each species and auto-calculated in Paleontological Statistics Software Package for Education and Data Analysis (PAST), version 3.23 (2013) (Hammer et al., 2001).

3.2.3.6 Spatial Partitioning

Comparison on partitioning in space understorey was tested by using Principal Component Analysis (PCA), the multivariate analysis in PAST, version 3.23 (2013) (Hammer et al., 2001) to find out height mostly associated with the birds, as applied by Fraterrigo and Rusak (2008).

3.2.3.7 Temporal Effect

Comparison on bird abundance among visits by using Kruskal-Wallis and rarefaction curves was produced in PAST, version 3.23 (2013) (Hammer et al., 2001). The latter investigated the relationships between the number of species and individuals in all four visits. Relationships between numbers of babbler individuals and rainfall record were presented in a rarefaction curve.

3.3 Results

3.3.1 Avifauna Assemblages

3.3.1.1 Diversity of Avifauna at Pelagus

A total of 1335 individuals comprising 106 species (herein termed all species) from 27 families of birds were mist-netted throughout the sampling (Appendix 3). The most dominant family was Nectariinidae, which account for 16 species and 328 individuals recorded, followed by Pycnonotidae, with 13 species and 239 individuals and Muscicapidae 14 species but relatively low in the account of individual counts (80 only). Nine families were recorded with just a single species, namely Columbidae, Podargidae, Indicatoridae, Pittidae, Irenidae, Dicruridae, Corvidae, Megaluridae and Rhipiduridae. Of these, *Phylloscopus borealis* (Arctic Warbler) from Megaluridae and *Platylophus galericulatus* (Crested Jay) from Corvidae were rarely caught and with only one individual representative of the families.

The most common mist-netted species over the sampling periods was one of the nectarivorous birds, *Arachnothera longistra* (Little Spiderhunter) with a total of 217 individuals. Secondly, highest number caught species was *Stachyris erythroptera* (Chestnut-winged Babbler) of Timaliidae, with 67 individuals.

3.3.1.2 Feeding Guild

Seven feeding guilds were defined in this study as mentioned earlier in Table 3.4 (adapted from Pang et al., 2017). Of all seven feeding guilds recorded in this study, most netted guild for both species and individual were insectivore (Table 3.3), which babblers also belong to. Total numbers of species and individual of babbler contribute 34.0% and 57.7% to this dominant guild, respectively. This indicated that the understorey forested

areas were commonly occupied by this insectivore, followed by frugivore-insectivore, nectarivore, carnivore-insectivore, frugivore, insect-frugivore and granivore.

Table 3.3: Total number of species and individuals from avian assemblages in accordance to the feeding guilds recorded from Pelagus, Kapit.

No.	Feeding guild	Species, %	Individuals, %
1.	Insectivore	44.8	41.4
2.	Nectarivore	14.3	24.0
3.	Frugivore	4.7	2.4
4.	Granivore	1.8	0.9
5.	Frugivore-Insectivore	21.0	26.4
6.	Carnivore-Insectivore	8.6	3.9
7.	Insectivore-Frugivore	4.8	1.0

3.3.2 Babbler Community

A total of 315 individuals representing 16 targeted species (15% of all birds) were captured (Table 3.4). Capture rate shows the CWB was the most frequently captured species, following by the STB. Two species had the lowest captured rate, CBSB and BSTB.

The Whittaker plot (Figure 3.1) shows the commonness and rareness of babblers recorded in this study. Values of relative abundance (log) closer to 1 indicate common species while values closer to 0 indicate rarity. CWB was the most common species, followed by STB. Dots that is close to 1 at y-axis represent CWB and STB, as these species have the highest number of captured individuals. Towards to the right at x-axis, the dots are gradually descending as other babbler species were caught with fewer individuals than the former two. Species with relative abundance close to 0 are considered species that rarely caught in this current study, for example, CBSB and BSTB. This plot indicates that the occurrence of babbler species in the understorey of the sampling stations varied.

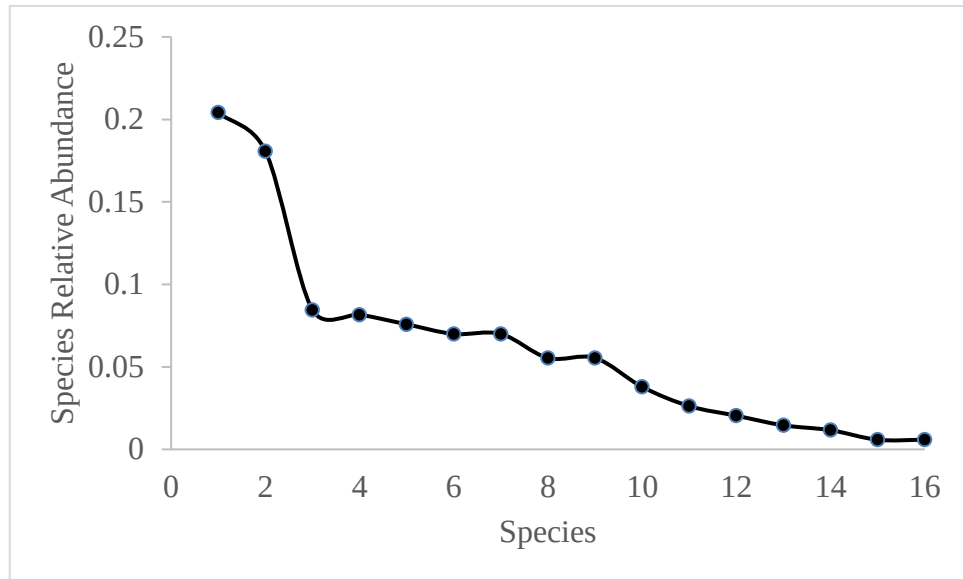


Figure 3.1: Rank abundance curve (Whittaker plot) of captured babblers in Pelagus, Kapit.

Table 3.4: List of babblers recorded from stations in Pelagus, Kapit.

	Bird species	Code	Total	Capture rate	Relative abundance
	<u>Timaliidae</u>				
1	<i>Pomatorhinus montanus</i> Chestnut-backed Scimitar Babbler	CBSB	2	0.0026	0.0061
2	<i>Stachyris nigricollis</i> Black-throated Babbler	BTB	26	0.0339	0.0793
3	<i>Stachyris maculata</i> Chestnut-rumped Babbler	CRB	7	0.0091	0.0213
4	<i>Stachyris poliocephala</i> Grey-headed Babbler	GHB	25	0.0326	0.0762
5	<i>Macronous borneensis borneensis</i> Bold-striped Tit-babbler	BSTB	2	0.0026	0.0061
6	<i>Macronous ptilosus</i> Fluffy-backed Tit-babbler	FBTB	25	0.0326	0.0762
7	<i>Stachyris erythroptera</i> Chestnut-winged Babbler	CWB	65	0.0846	0.1982
8	<i>Malacopteron affine</i> Sooty-capped Babbler	SCaB	18	0.0234	0.0549
	<u>Pellorneidae</u>				
9	<i>Malacopteron cinerum</i> Scaly-crowned Babbler	SCB	16	0.0208	0.0488
10	<i>Malacopteron magnum</i> Rufous-crowned Babbler	RCB	10	0.0130	0.0305
11	<i>Malacopteron magnirostre</i> Moustached Babbler	MB	4	0.0052	0.0122
12	<i>Pellorneum capistratum</i> Black-capped Babbler	BCB	13	0.0169	0.0396
13	<i>Trichastoma pyrrogenys</i> Short-tailed Babbler	STB	52	0.0677	0.1585
14	<i>Trichastoma bicolor</i> Ferruginous Babbler	FB	19	0.0247	0.0579
15	<i>Trichastoma rostratum</i> White-chested Babbler	WCB	27	0.0352	0.0823
16	<i>Trichastoma sepiarium</i> Horsfield's Babbler	HB	4	0.0052	0.0122

Species accumulative curve (Figure 3.2) indicates that all babbler species in Pelagus have been recorded in the current study as the line reaches to the plateau. These 16 babblers accounted from these 10 sampling areas could represent the population of families Timaliidae and Pellorneidae in Pelagus area. Chances to capture other species in the areas are high, as the curve of all species is still ascending. The ascending line which reaches to its asymptote in Figure 3.3 also indicates that all babbler species have been discovered in Pelagus area on the 40th day of sampling days. CWB and STB were found throughout the sampling days. CBSB and BSTB were encountered, respectively, twice and three times on the 24th, 25th and 28th days.

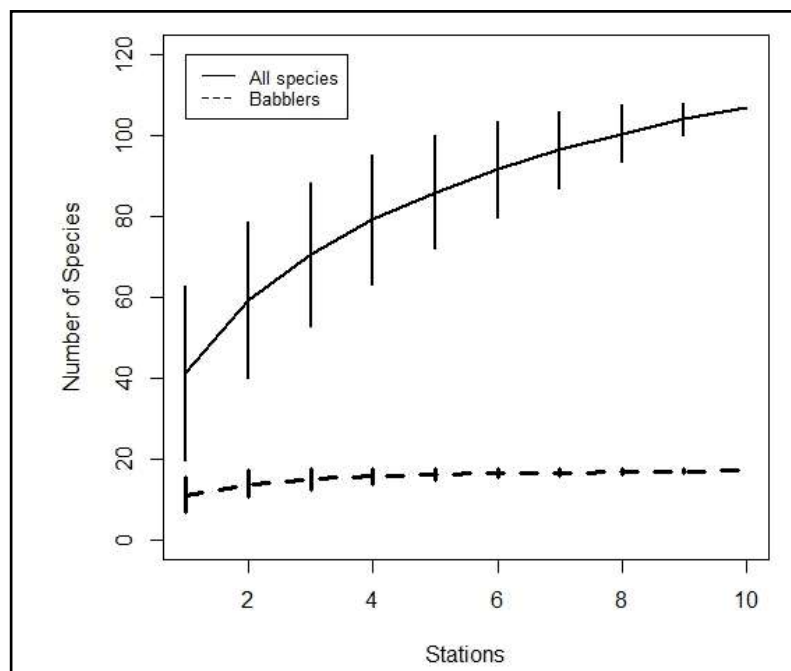


Figure 3.2: Species accumulation curves of all 106 captured bird species and of babblers captured from sampling stations. Solid line indicates bird species captured and dotted line is the babblers, recorded in the current study. Bars indicate standard deviations.

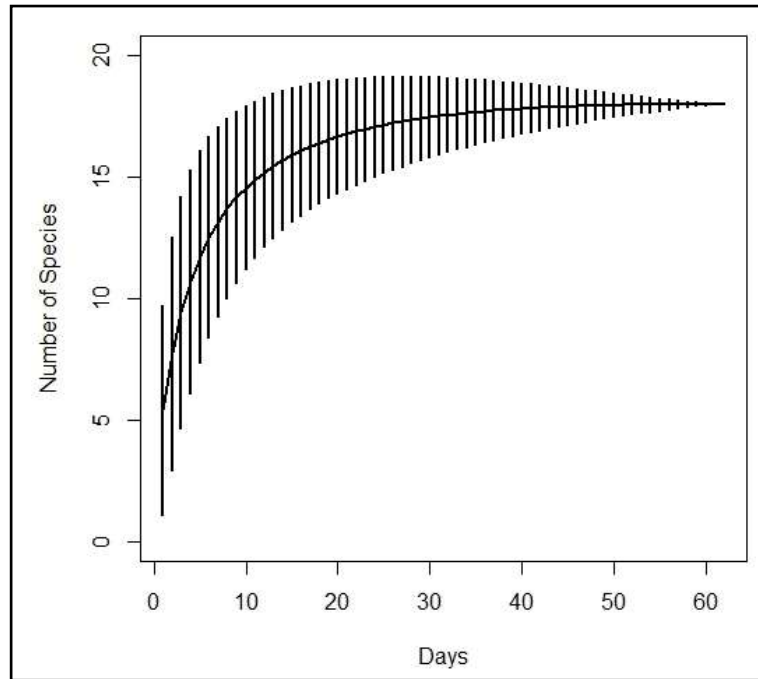


Figure 3.3: Species accumulation curve of babbler against sampling days in this study. Bars indicate the standard deviations.

The occupancy and netting probability of each babbler species in this study were analysed. Figure 3.4 shows that occupancy of 16 babblers at all sites is high, which is closer to 1, except CBSB, but the netting probability of all species is relatively low.

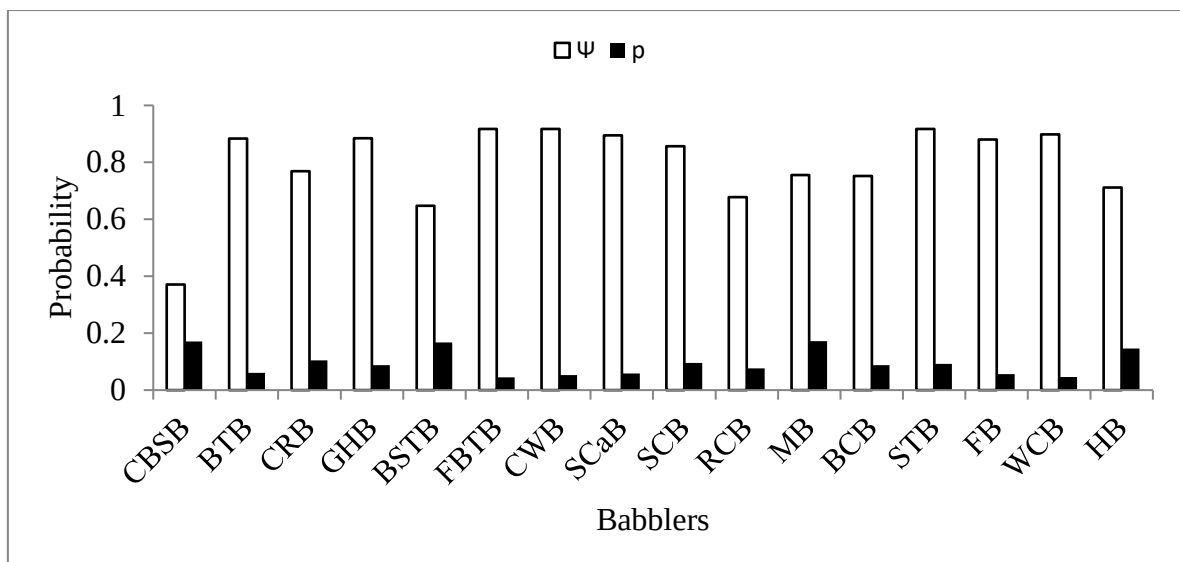


Figure 3.4: Occupancy (Ψ / psi) and netting probability (p) of each babbler species recorded in Pelagus, Kapit.

3.3.3 Spatial Distribution (Horizontal and Vertical)

3.3.3.1 Horizontal Distribution

Table 3.5 shows distribution of species at the visited stations with different disturbance levels. The abundance of the species and diversity of babbler were not correlated to disturbances at each visited replicate site, nor to the vegetation or distance. This uncorrelated relationship may be due to the different responses of babbler to different covariates in the environment.

Table 3.5: Distribution of species belonging to families of Timaliidae and Pellorneidae at stations visited in Pelagus, Kapit.

		PNP	Nanga Pelagus			Nanga Benin			Nanga Peraran		
		PF	100 m	500 m	1,000 m	100 m	500 m	1,000 m	100 m	500 m	1,000 m
			AF	SF	SF	AF	AF	SF	AF	SF	LF
Species		12.45 [#]	21.87 [#]	14.38 [#]	11.94 [#]	19.26 [#]	15.42 [#]	14.44 [#]	16.52 [#]	14.24 [#]	16.30 [#]
1	CBSB	0	0	0	0	0	0	0	0	2	0
2	BTB	1	2	3	2	2	3	0	4	2	7
3	CRB	0	0	0	2	0	0	1	0	2	2
4	GHB	0	8	4	6	2	2	1	0	1	1
5	BSTB	0	1	0	0	0	0	0	1	0	0
6	FBTB	3	2	1	1	2	3	3	1	2	7
7	CWB	6	7	8	4	6	7	5	3	2	17
8	ScaB	5	1	0	3	0	0	3	3	2	1
9	SCB	5	0	0	3	0	1	4	1	1	1
1	RCB	4	1	0	1	0	0	0	0	0	4
1	MB	2	0	0	1	0	0	0	0	0	1
1	BCB	5	1	2	0	2	0	0	1	0	2
1	STB	11	5	0	7	2	2	4	6	4	11
1	FB	1	3	1	8	0	2	1	2	0	1
1	WCB	0	5	0	2	4	1	2	4	2	7
1	HB	0	1	1	1	0	0	0	0	1	0
Total		43	37	20	41	20	21	24	26	21	62
H'		2.098	2.194	1.653	2.316	1.834	1.930	2.048	2.111	2.318	2.132

Of 29 recaptured babblers, a majority were recaptured from the same station. Only four individuals of three species were recaptured from different stations and at different times (Table 3.6); they are CWB, SCB and GHB. Three individuals were captured twice, while one species was captured thrice. This also suggests most babblers confined in an area and fly short distance of not more than 500 m. A few of them used different spaces in the forest.

Table 3.6: List of recaptured babblers, individual and capture timeline.

Species	Ring no.	First capture		Recaptured		3 rd Captured	
		Where	Date	Where	Date	Where	Date
CWB	A12328	500 m	17 Aug	1000 m	12 Nov	-	-
SCB	A12630	100 m	15 Aug	500 m	5 Nov	-	-
SCB	A09205	1000 m	3 April	1000 m	10 Nov	-	-
GHB	B10560	1000 m	13 Jan	1000 m	30 Mar	500 m	9 Nov

Occupancy (psi) and probability of netting, (p) of babblers in Pelagus

Table 3.7 lists out the AICc values of covariates which could possibly affect the babbler the most on each species occupancy and netting probability. It suggests that the responses to the environmental characteristics (the covariates) varied among babblers. Covariate(s) with the lowest AICc which is potentially to be the most parsimonious model if the difference between two lowest values is greater than 2. It also suggests that the covariate(s) affect the occupancy and netting probability of a species could be similar or otherwise.

The summary of Table 3.7 is revealed in Table 3.8. All eight covariates play a role in influencing both occupancy and netting probability of babblers, except PET, indicating the dogs and cats kept by the local, that enter the forest have low effect to the study

subject. It suggests that three babbler species CRB, RCB and HB are highly sensitive than other babblers as only one covariate could affect their occupancy and netting probability.

Table 3.7: AICc values for each babbler species in this study corresponding to the covariates.

Babbler		DIST	ELE	MAN	PET	FT	CAN	TP	LLD	DBH
CBSB	psi (~.)	37.07	37.07	-	37.07	41.57	29.25	37.07	28.89	37.07
	p (~.)	37.07	28.83	-	-	-	27.71	-	-	-
BTB	psi (~.)	358.56	358.78	358.95	358.66	355.88	357.31	358.20	358.95	358.56
	p (~.)	358.27	355.53	358.91	357.91	352.19	353.94	356.16	358.94	354.04
CRB	psi (~.)	198.90	206.14	215.24	221.12	205.98	230.46	225.51	228.82	226.05
	p (~.)	202.26	217.82	225.31	-	-	230.05	228.55	227.94	230.30
GHB	psi (~.)	251.15	252.10	251.93	252.01	247.76	247.36	252.04	251.53	250.40
	p (~.)	249.17	247.17	247.06	-	247.13	245.02	252.07	248.19	242.31
BSTB	psi (~.)	33.38	32.29	32.30	36.23	37.93	36.65	35.65	37.02	36.02
	p (~.)	34.32	33.58	34.93	36.18	37.93	37.06	36.91	37.01	35.63
FBTB	psi (~.)	292.82	296.76	298.04	297.46	299.95	297.11	298.26	298.23	298.87
	p (~.)	295.12	287.10	298.94	297.80	286.65	289.48	298.34	297.93	297.788
CWB	psi (~.)	632.28	632.98	632.08	630.06	631.55	631.21	623.77	625.19	629.55
	p (~.)	632.35	631.80	632.95	633.02	631.59	630.86	631.29	627.76	632.92
SCaB	psi (~.)	210.56	209.83	210.04	208.18	212.04	210.15	207.05	204.42	207.64
	p (~.)	210.61	209.68	208.97	207.77	209.17	210.59	204.53	203.48	205.38
SCB	psi (~.)	215.77	204.12	203.91	210.55	208.26	216.14	216.04	211.01	213.37
	p (~.)	216.96	215.05	206.85	210.55	215.74	216.62	213.84	210.01	211.72
RCB	psi (~.)	81.40	83.10	82.23	-	-	82.27	74.24	83.84	65.62
	p (~.)	84.64	82.12	83.59	82.45	-	83.11	78.37	84.74	72.37
MB	psi (~.)	57.94	56.86	57.87	57.28	-	82.27	-	55.49	55.91
	p (~.)	58.45	56.70	56.84	-	-	82.65	-	55.49	54.00
BCB	psi (~.)	163.88	166.94	167.02	167.02	162.49	166.81	163.30	167.00	164.71
	p (~.)	160.60	166.76	167.00	167.00	158.19	166.41	161.37	166.89	158.43
STB	psi (~.)	479.81	475.09	477.07	477.37	474.24	480.86	478.86	478.83	476.54
	p (~.)	479.95	480.87	478.90	480.64	483.27	480.75	479.89	481.06	481.06

Table 3.7 continued

FB	psi (~.)	250.76	260.63	259.82	260.27	261.48	261.81	262.33	260.95	263.53
	p (~.)	257.54	263.14	263.27	263.49	262.96	258.17	261.38	262.51	262.42
WCB	psi (~.)	337.74	336.67	340.12	340.16	339.53	338.74	339.87	338.38	340.16
	p (~.)	340.14	340.05	339.53	340.17	344.50	339.77	338.84	340.01	340.10
HB	psi (~.)	101.54	101.40	101.10	101.46	101.43	98.35	101.43	100.44	100.08
	p (~.)	101.42	100.80	101.41	-	103.08	96.12	100.78	101.33	100.07

Abbreviations: psi (~.) means occupancy depends on, p (~.) means the probability of netting depends on. The abbreviations in the table are referring to distance (DIST), elevation (ELE), human (MAN), pet (PET), forest types (FT), canopy cover (CAN), tree proportion (TP), leaf litter depth (LLD) and diameter breast height (DBH).

Table 3.8: Most parsimonious model(s) to predict occupancy and netting probability of 16 babblers recorded in Pelagus. psi (~.) means occupancy depends on, p (~.) means the probability of netting depends on.

Babbler	psi(~.)	p(~.)
CBSB	LLD, CAN	CAN, ELE
BTB	FT, CAN	FT, CAN, DBH
CRB	DIST	DIST
GHB	FT, CAN	DBH, CAN
BSTB	ELE, MAN	ELE, DBH, MAN
FBTB	DIST	FT, ELE
CWB	TP, LLD	LLD
SCaB	LLD	LLD, TP
SCB	MAN, ELE	MAN
RCB	DBH	DBH
MB	LLD, DBH	DBH
BCB	FT, TP	FT, DBH
STB	FT, ELE	MAN, TP
FB	DIST	DIST, CAN
WCB	ELE, DIST	TP, MAN
HB	CAN	CAN

Fitting into a community with other sympatric understory insectivorous birds, babbler species react differently to the environments and their occupancies depend on different covariate(s), respectively. The occupancies of the 16 babblers in this study would either be influenced by a covariate such as DIST, LLD, DBH and CAN, respectively; or by the combination of two covariates, as shown above. This implies that sympatric species in a confined be area would able to coexist by partitioning their niches and deal with the disturbances, respectively.

Occupancies of six babblers were influenced by one covariate. SCaB prefers areas with litter depth average 5–9 cm; RCB was frequently encountered in areas with greater number of trees with dbh below 15 cm; HB selects areas with 93% and above canopy cover and CRB, FBTB and FB choose areas that are away from the settlement.

Babblers that depend on more than one covariate, are CBSB, BTB, GHB, BSTB, CWB, SCB, MB, BCB, STB and WCB. The occupancy of CBSB is affected by LLD and CAN as it forages on prey and peers into crevices and branches on the forest floor. Dry forest floor resulting from high intensity of sunlight and heat when canopy cover is small, CBSB may lose its prey and move on for food resources. Two covariates, FT and CAN influence the occupancies of BTB and GHB; BTB prefers area occupied by logged forests and reduced canopy cover. Unlike BTB, GHB favours agroforest and relatively denser canopy covers. BCB was captured often in primary forests in PNP. Forest type and elevation are likely co-supporting models to the occupancies of STB, as this species was encountered most often at both primary forest and logged-over forest, and both forests were located at a higher elevation compared to other forests.

Alongside elevation, the presence of human influence the occupancies of BSTB and SCB. The former was caught from the sampling sites that are at low elevations and closer to human settlements and was previously reported to occur in disturbed areas, such as oil palm plantation. In contrast, SCB prefers high elevation areas with lower human disturbance. Covariates influencing occupancies of CRB and FBTB are distance and canopy. No CRB was found at stations closest to humans, whereby 80% of FBTB were captured at stations 500 m or more away from settlements.

Sixteen species of babbler are known in the stations but are not netted. The netting probabilities of all species was relatively low. This could be because the movement of babblers could be dynamic and home range is larger than expected, their occurrence in those sampling stations was transient during sampling periods. Babblers might have also learnt to avoid flying to the area where they were caught before.

Amongst tested covariates, DBH influenced the most babblers, six, following by CAN with five babblers, MAN with four babblers, ELE, FT, and TP with three babblers, DIST and LLD had the least influence on the netting probability, only two were affected.

Netting probability of six babbler species was best supported by one covariate. The results show that CRB was netted often in the area far from human settlements or they avoided being in the area closer to disturbances. Being a ground-dweller and foraging on the forest ground, CWB's netting probability is depending on shallow leaf litter. As this is a small species, the tendency of foraging on the forest floor with less leaf litter is higher; thus, it was caught often at PR1000 where the leaf litter depth was the least, 6.0 mm on average. RCB and MB were netted greater in number in stations which have more younger trees with dbh less than 15 cm. HB has a higher tendency to be trapped in stations with denser canopy cover.

In this study, a covariate that affect one's occupancy would most likely influence its netting probability as well. This does not apply to FBTB, STB and WCB. DIST affected the occupancy of FBTB but the netting probability depends on FT and ELE. STB's occupancy relies on FT and ELE but netting probability on MAN and TP. Presence of WCB influenced by ELE and DIST, while netting probability of it by TP and MAN.

3.3.3.2 Vertical Distribution

Sharing understorey niches with other sympatric species in the forest, babblers are found to partition their use of vertical space, and Table 3.9 shows a decreasing trend in individual of babblers captured from the shelf closest to ground to the top shelf at 3.6 m above ground. Ninety-five percent of babblers occupied the vertical space up to 3.0 m. Only 10 individuals of five species had a broader space utilisation up to 3.6 m, namely

BTB, CRB, SCaB, STB and FB. CBSB and BSTB were the only two species not captured in the lowest shelf.

Table 3.9: Frequency of the target babbler species caught at respective shelf.

No.	Species	Shelf (m)					
		1 (0–0.6)	2 (0.6–1.2)	3 (1.2–1.8)	4 (1.8–2.4)	5 (2.4–3.0)	6 (3.0–3.6)
1	CBSB	0	1	0	1	0	0
2	BTB	6	8	11	0	1	1
3	CRB	1	2	2	1	0	6
4	GHB	9	8	6	4	0	0
5	BSTB	0	0	0	1	0	0
6	FBTB	6	8	6	1	1	0
7	CWB	24	19	12	9	6	0
8	SCaB	3	8	4	2	0	1
9	SCB	6	5	3	2	0	0
10	RCB	5	2	2	0	1	0
11	MB	1	0	1	0	2	0
12	BCB	4	5	2	2	0	0
13	STB	35	13	4	4	2	1
14	FB	5	5	4	4	2	1
15	WCB	2	13	8	5	1	0
16	HB	1	1	0	2	2	0
Total		108	98	65	38	18	10

Figure 3.5 shows the correlation between shelves and targeted species obtained from Principal Component Analysis (PCA). The length of the lines indicates the relationship between babblers' frequency encounter and the height of nets above ground. The lines represent significance each of the shelf is to the birds. The longer it is, the more significant it is. The line S1 (Shelf 1) is the longest among all as most individuals of babblers were caught in that shelf, followed up by S2 (Shelf 2), S3 (Shelf 3), S4 (Shelf 4), S5 (Shelf 5) and S6 (Shelf 6). Line S6 is the shortest and obviously the least significant to babblers, as only 3% of total individuals were caught therein.

Each dot represents the species which shows how the species are grouped in terms of space utilisation in the understorey. In terms of spatial utilisation, CWB and STB are microhabitat specialist restricted to the lower ground. STB have the most individuals utilising the space nearer to the ground (0–0.6 m), while CWB used space above ground 0–1.2 m as they were caught most in Shelf 1 and 2.

Seven species, WB, BTB, FBTB, GHB, SCB, FB and SCaB are clustered close to each other around the centroid, as they have broader space usage as well as the individuals of each species distribute evenly in the shelves, they caught in. Another group of six species (CCY, BCB, CRB, HB, MB and RCB) were located further away from the centroid, indicating their preference for space in the forest within 3.6 m is unclear. CBSB and BSTB do not appear on the graph. This could be due to the insufficiency of data for these species.

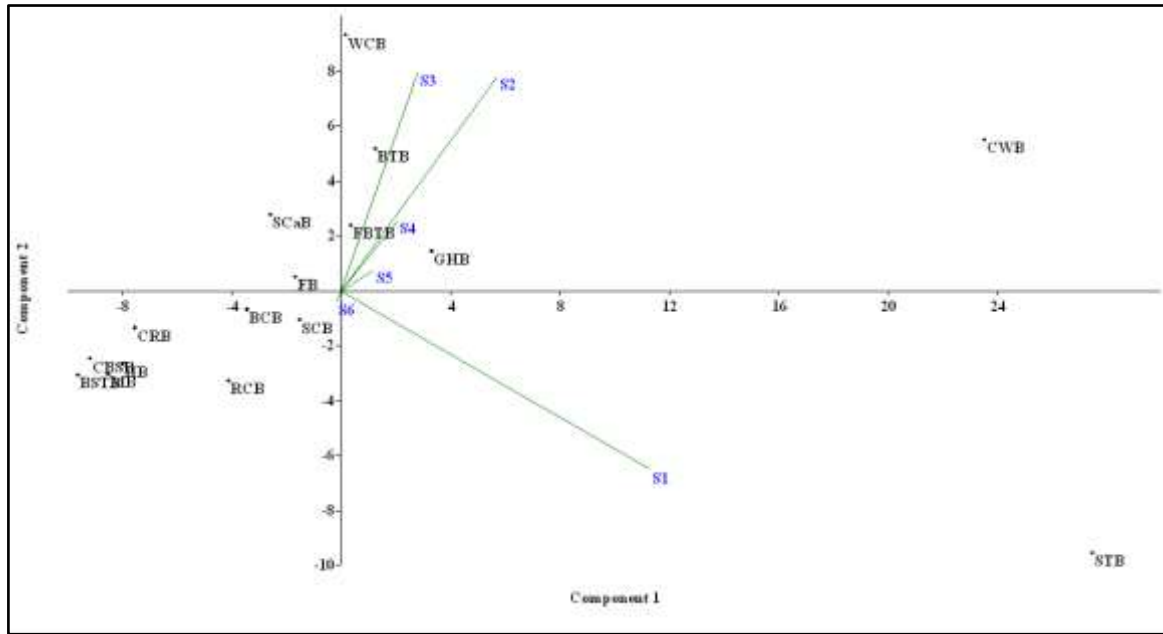


Figure 3.5: The grouping of babblers corresponding to space utilisation in the forested areas, Pelagus, Kapit.

3.3.4 Temporal pattern

The rainfall records at Kapit town (Figure 3.6) show that sampling period (2) in March – April 2016 had the most amount of precipitation by volume (318.4 mm), followed by sampling conducted in December 2015 – January 2016 (1) received 298.6 mm rainfall, sampling in November 2016 (4) had 179.4 mm and the least rainfall (69.0 mm) received in August 2016 (3). The horizontal line in the below figure indicates the average value (216.35 mm) of the rainfall received through the period when visits of sampling were conducted. This implies that the rainfall during December 2015 – January 2016 and March – April 2016 were above average, while the two subsequent sampling periods were below.

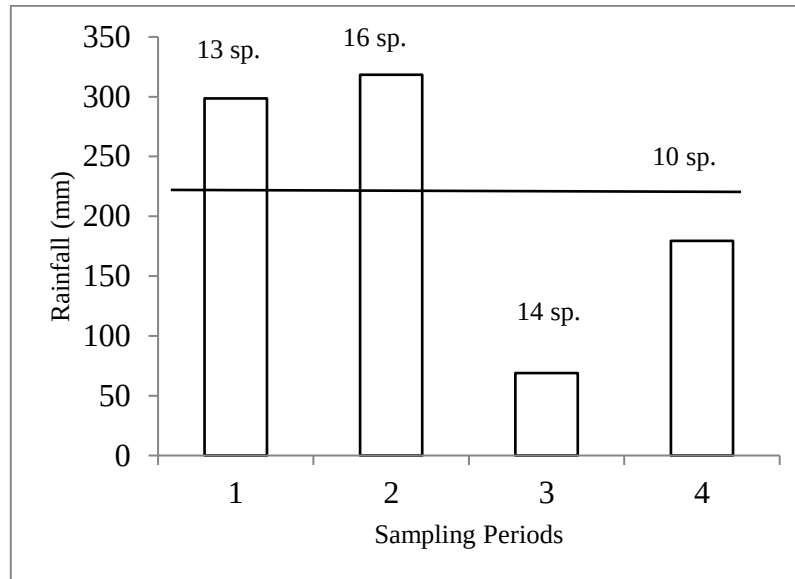


Figure 3.6: Accumulation of rainfall (mm) over the sampling days of Kapit. Source: Department of Meteorology Malaysia, Sarawak branch. The horizontal line indicates the average values of rainfall during the sampling period.

Among all four sampling periods, the greatest number of species and individuals (16 and 141) were encountered in March – April 2016, the wettest period when the highest rainfall recorded. Second highest number record of babblers (14 species and 73 individuals) happened in August, the driest period with the lowest rainfall. Sampling in December 2015 – January 2016 had higher number of species captured, but representative slightly lower number of individuals (13 sp. 68 individuals) captured compared to November 2016 (10 species and 70 individuals).

The rarefaction curve (Figure 3.7) shows that the highest babbler diversity was recorded in March – April 2016; while the diversity of babblers captured in other sampling periods in different months was far lower than March – April 2016. Results obtained from Kruskal-Wallis Test show that babbler abundance at 10 stations ($n = 10$) is significantly different (p value = 0.004174) among four sampling periods ($t = 4$). Number of birds

captured in March – April 2016 was significantly higher than those in three other periods (Table 3.10). This suggests that babbler abundance could have affected by the rainfall.

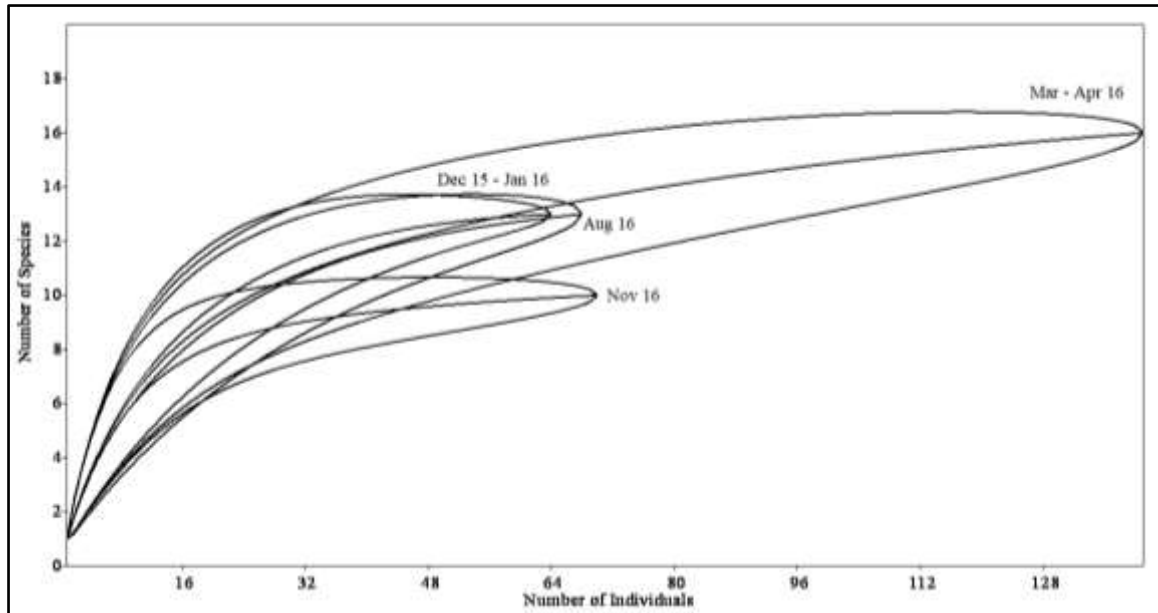


Figure 3.7: Rarefaction curves represent the relationship between number of babbler individuals (x-axis) and the number of babbler species (y-axis) during visits.

Table 3.10: Significance level from Kruskal-Wallis test on the bird abundance among four samplings conducted in different months in Pelagus, Kapit.

	Mar – Apr 16	Aug16	Nov 16
Dec 15 – Jan 16	0.003129	0.5687	0.7327
Mar – Apr 16		0.003485	0.006362
Aug 16			0.568

3.4 Discussion

3.4.1 Responses of Babbler to Disturbance

Of 106 species recorded in the sampled forests, 16 species (15%) were understorey babblers belonging to two families, Timaliidae and Pellorneidae. Species accumulation curve revealed that more species are to be found at the sampled forests, but not for babblers. This implies that the forests of all stations were likely to house these 16 species out of 35 babblers reported from Borneo.

Previous researches claimed that diversity of bird in primary forest are high but declined in disturbed forest, especially the habitat-specialist species (Zakaria et al., 2005; Barlow et al., 2006; Posa & Sodhi, 2006; Gomes et al., 2008; Burivalova et al., 2014). Others reported that disturbed forest were refuges for a high number of bird species, especially habitat-generalists which are able to adapt to disturbed areas (Edwards et al., 2011; Bryan et al., 2013; Battisti & Fanelli, 2016). In this study, the diversity of babbler, was not correlated to the disturbance level in the areas.

Having recorded the highest number of babbler individuals caught, amounting to 63 individuals, PR1000 also had the highest number of species, 13. Sharing the same number of species with PR1000 was PL1000 but had fewer individuals. PNP had only 10 species and 43 individuals were captured. In PNP, the diversity of babbler ranked sixth after more disturbed stations such as PL100, PL500, PL1000 and PL100.

Forest alterations which affect canopy closure, tree size and trees species contributes to the disturbances which in turn affect terrestrial fauna species, such as forest rats, birds and insects (Posa & Sodhi, 2006; Chapman & Reich, 2007; Cusack et al., 2015). In the context of the Pelagus region, stations are expected to differ in diversity, as a

reflection of site-specific disturbance. Highly adaptive species may survive in all stations regardless, sensitive species may confine to certain regions for survival. Sharing common characters and being in the same taxonomic group, babblers have their own distinctive life histories that is shaped by certain environment covariates influencing them as a group.

3.4.2 Occupancy (ψ) and Netting Probability (p) of Babblers in Pelagus

The occupancy of all babblers was high. This could imply that the babblers are adaptive to the disturbance levels of the study sites. That does not apply to CBSB. Its occupancy was apparently lower than others. It may indicate that adaptation to the disturbances was low and lead to immigration. The occupancy of CBSB was affected by LLD and CAN as they forage and peer into crevices and branches on the forest floor (Lambert, 1992). Dry forest floor resulted from the high intensity of sunlight and heat when canopy cover is small, CBSB may lose its prey and move to other places for food resources. In addition, this species could be habitat-specialist, as it is known to be a scarce resident in the forests of Borneo, and previous observation reported the species in unlogged forests (Lambert, 1992).

Mansor et al. (2011) reported that BCB is found in primary forests while high rate of capture of this species in this study shows that BCB may inhabit this forest type, despite it having comparatively higher number of pioneer trees (dbh under 15 cm). CRB was found to avoid human settlements, as reported by Bjørvik et al. (2015).

Despite 16 babblers occupying the sampled stations, they were not all detectable or in the context of this study, netted easily. The netting probability of all species was low (< 0.2). This is probably because the babblers can see and avoided the nets and due to the topography of the area which limited suitable netting location. Also, it could indicate that

the babblers are sensitive to the surrounding during the survey. It could also be the babblers are more dynamic in their movement and home range is larger than expected, so that their occurrence in those sampling stations was transient (Rosenber & Cooper, 1990).

CWB is known to be a ground dweller and foraging on the forest ground (Mansor et al., 2015; Styring et al., 2016; Pang et al., 2017), thus, its netting probability is dependent on shallow leaf litter. As this is a small species, the tendency to forage on the forest floor with shallow leaf litter is higher; thus, it was caught in higher number at PR1000 where the leaf litter depth was thinnest at 6 mm.

3.4.3 Spatial and Temporal Distribution of Babblers in Pelagus

A study conducted in northern Australia covered a community of birds that may have higher number of ecological dissimilarities (Mohd-Azlan et al., 2014), similar to the report by Thivyanthan (2016) which covered birds from different groups that show a wider range in niche partitioning, both vertically and horizontally. In contrast, the vertical stratification ranged would be restricted if the study subjects are similar ecologically. Kumar et al. (2009) and Lara et al. (2015) focused on similar respective bird groups which share habitats but partition their niches on the same tree.

Compared to local studies, babblers were barely recorded at the canopy as none was recorded by Rahman (2002). Studies that involve babblers demonstrate that their vertical stratification ranges were wider than what this study reported. For example, RCB, MB, SCaB and CWB were reported by Lambert (1992) and Mansor and Ramli (2017) that utilised space higher than in this study. Habitats play an important role. Study sites of both studies were at protected area with primary forests. The forest types in this study were more disturbed and may be better explored in the understorey space. The bushes, seedlings

and saplings that have grown up to 1.8 m in the forest may serve as a protective layer from predators especially to babblers which in comparatively, are small-bodied birds (Pang et al., 2017). These layers would at least, aid in providing camouflage and shelter from predators. Hence, sixteen babblers in this study partitioning their niches in order to coexist with syntopic species as reported by Styring et al. (2016).

Species count made in March – April although was slightly higher but the number of netted individuals in that visit was significantly greater than those in other sampling periods. High volume of rainfall during this period was unlikely to affect babbler activities. This is because the rains occur mostly at night while diurnal babblers were active during the day (Bednekoff & Houston, 1994). The prey base could be sufficient throughout the year to supply babblers, compared to other guilds in the forest without the need to immigrate, as reported in Gleditsch et al. (2017) and Lima and Manhaes (2017).

Chan et al. (2008) demonstrate that seven species from the bird community at riparian secondary forest were recorded in greater number during wet season than dry season. There were also seven babbler species in this study that show the same trend as mentioned. Five of them, BTB, FBTB, CWB, SCB and WCB were netted in much higher number in March – April 2015 when the rainfall was also the highest while CBSB and FBTB were only netted during this period.

Table 3.4 shows that the occupancies of these 16 babblers in the sampling stations are all higher than 50%, except CBSB, suggesting that their presence in the areas are high regardless season. High capture number of babblers during March – April 2015 when rainfall was high probably because they were more actively foraging to meet the needed for nutrient to generate body heat and keep warm after a cold raining night was over.

Additionally, raining season would shorten their foraging time. Higher number of babblers could be netted after raining because they were out foraging for food.

When the resources are scarce, they may migrate to other sites. Migration among microhabitats within sites in Pelagus could be temporary. Babblers could migrate back to their habitats (Werema, 2015), when food resources stabilise.

3.5 Conclusion

Of all 106 avifauna species recorded in all stations throughout the sampling periods, 16 were babbler species from Timaliidae and Pellorneidae families. The most common babblers found were CWB, followed by STB and WCB; the least often recorded were CBSB and BSTB, with just two individuals.

Occupancy probabilities varied among babblers. Elevation was the best covariates to describe four babblers, BSTB, SCB, FB and WCB. Forest type and leaf litter depth were most suitable for three babblers, respectively. The former influences BTB, BCB and STB whereby the latter affects CBSB, SCaB and MB. Distance and canopy cover, both show effect on the occupancies of CRB and FBTB, and GHB and HB, respectively. Both the presence of human and their animals did not affect the occupancy of any babbler species.

Babblers are shown to be able to partition the understorey space vertically. STB and CWB occupy space closer to the ground while GHB, FBTB, FB, BTB, WCB, SCB and SCaB utilised above-ground space up to 2.4 m. Most babblers were not affected by distance away from human settlements, except for CRB and FBTB which were captured in greater number at stations far from longhouses.

The higher rainfall in March – April 2016 did not seem to reduce the capture probability, in fact the number of babblers captured was surprisingly the highest. This could be on account of the rain usually occurring at night and did not affect babbler activity the following day.

A number of environmental covariates identified in Chapter 1 affects the occupancy and netting probability of babblers, indicating that babbler species are responsive to changes in their environment. These covariates or combination of them affects each species in different ways thus shaping their use of space, which in turn enable them to utilise food resources in a sustainable manner and ensure their survival even in disturbed habitat.

CHAPTER 4

PREY DISTRIBUTION OF UNDERSTOREY BABBLERS IN PELAGUS, KAPIT

4.1 Introduction

In Chapter 3, babblers were shown to occupy a range of habitats, from relatively undisturbed to severely disturbed forest. The reason for this resilience is their ability to partition their use of space, especially vertical space, and thus exploit food resources efficiently. This chapter investigates the distribution of potential prey of understory insectivorous babblers, to understand further their mechanism for coexistence.

Feeding is the process of searching or foraging, manipulating and ingesting of the food materials while foraging is the activity carried out by the animal in searching, hunting and reaching food (Allaby, 2003). Food sources are biological items (both plants and animals) found in the wild that provide nutrients to other animals while prey items are specific animals that are hunted and consumed by other animals (Allaby, 1991; Capinera, 2010). Food availability refers to the abundance of the food resources at the time and place where an animal is foraging while food preference is the choice of dietary items regardless of the availability (Capinera, 2010).

4.1.1 Potential Prey

4.1.1.1 Arthropods

Alongside plants as the primary producers and most important element in the food webs, invertebrate, particularly arthropods are important due to their high usage in the trophic web. Fleming, (1991) demonstrate that 107 families of mammal and 135 families of bird preferred insects as prey. Total estimated consumption by insectivorous birds in the

tropics was estimated at more than 300 million tons per year. Of this figure, arthropods consumption by insectivorous birds in tropical forests was greater than the combination of any other biomes, such as savannas, grasslands, croplands, deserts and arctic tundra (Nyffeler et al., 2018).

Several characteristics make arthropods a perfect package to be important ecologically as food source: (i) wide distribution, (ii) no distinct seasonal variation (iii) high availability (iv) sessile arthropods are easy targets for their predators, especially those on the forest floor or are slow-flyers (Capinera, 2010).

The distribution of arthropods are not only widespread globally in different biomes, but also in just a biome, tropical for one, they are found in almost all habitats such as water body, forest floor, on the leaves, in the tree trunk and in the canopy (Murakami, 2002; Chan et al., 2008; Capinera, 2010). Although they are sensitive to weather or seasonal change, their mobility is limited. Arthropods such as ants, termites, bees and flies are favourable targets for food of birds since they often congregate in large numbers and are numerically abundant (Wong, 1986; Gaiotti & Pinho, 2013; Ceresa et al., 2016). Coleopterans are dominant in insectivorous bird diets (Siqueira et al., 2015; Sam et al., 2017) could be due to their limited mobility that make them easy to be caught when they move slowly on the forest floor.

4.1.1.2 Non-arthropod Items

Shifting from primary to secondary diet, which comprising non-arthropods item, are common to insectivorous birds, especially when arthropods are scarce. Two species, *Diucadiuca* spp. (Common Diuca-Finch) and *Zonotrichia capensis* (Rufous-collared

Sparrow) in grazed habitats exhibit diet flexibility by consuming higher number of small grass and forb seeds (Marone et al., 2017).

Five primary insectivorous migratory Parulid warbler species, the *Setophaga ruticilla* (American Redstart), *Mniotilta varia* (Black-and-White Warbler), *S. caerulescens* (Black-throated Blue Warbler), *S. americana* (Northern Parula) and *S. discolor* (Prairie Warbler) opportunistically feed on both coleopteran and coffee berry borers when they migrate to the coffee plantation when their preferred-food was scarce. Occasionally, they forage on millipedes and centipedes when resident insectivorous birds consumed greater on larger and nutritious arthropods (Sherry et al., 2016).

4.1.2 Responses of Arthropods to Environmental Changes

Invertebrates are known to respond rapidly to changes in the environment, such as forest disturbances as even availability of dead wood and soil compaction in a microhabitat are known to affect them (Sodhi et al., 2010). Arthropod species that fail to adapt to changed environments are restricted in their geographical distributions and could also be selective in microhabitat requirements, for example, the canopy cover. Nevertheless, some species of moths (Lepidoptera) and dung beetles (Coleoptera) respond differently to change and may thrive in disturbed area (Hayes et al., 2009).

A study in Costa Rica showed that canopy opening was a determinantal to arthropod diversity (Holl et al., 2013). This same was carried out at a mixture of pastures, coffee plantations and vegetables farms showed that canopy opening was reported to be negatively correlated to the growth of saplings and seedlings, which directly affected the diversity of the arthropods on the forest floors. On the contrary, another study at a former pasture and plantation, also in Costa Rica, showed that canopy openness was unlikely to be

correlated with arthropod diversity (Cole et al., 2016). Studies on ants in Pantanal flood-plain, Mato Grosso do Sul, Brazil demonstrate that most ants that were sampled foraged and nested in soil. Marked seasonality shows that a greater species number of ants were found during wet season when the area was flooded. Instead of migrating to higher area that without flood, they moved from soil to tree canopy for resources (Soares et al., 2013).

Murakami (2002) demonstrated that the number of caterpillars in Tomakomai Experimental Forest of Hokkaido University in northern Japan varied both temporally and spatially. The numbers in the canopy peaked from May to mid-June, but was low in late June to July. Savitha et al. (2008) demonstrated that within an urbanised area in Bangalore city, India ant diversity was speciose with relatively higher number of rare species than in suburban and rural area. Nevertheless, urban areas were not the highest with regards to the abundance of the ants collected. Widespread ant species in urban areas suggest that some generalists among those species would acclimatise with changes in the surroundings.

The distribution of arthropods varies in primary and logged forests. Pseudoscorpiones (false scorpion or book scorpion) and Acarina (mites) are abundant in primary forests while Coleoptera (beetles), Diplopoda (millipedes) and Dictyoptera (cockroaches) are abundant in the logged forests of Danum Valley, Sabah (Burghouts et al., 1992). The diversity of Lepidoptera (butterflies), in another study, in Danum Valley Conservation Area and Ulu Segama Forest Reserve, Sabah, was reportedly higher in a primary forest than in a secondary one. The diversity of lepidopterans in the primary forest was higher during the wet season (October to January or September to February, in some years between 1985 to 1998), but became lower during the dry season from March to August (Hamer et al., 2005).

4.1.3 Research Problems, Objectives and Hypotheses

In the Chapter 3, it was shown that babblers use vertical space partitioning. The fact that many species coexist in a limited space suggests that (i) prey items are not limited in quantity (ii) babbler partition their use of resources through use of different foraging strategies. For example, CWB and Abbott's Babbler use similar proportion of foraging height (> 0–2 m above ground) and foraging substrate (dead leaves) but differ in the use of attack manoeuvres (Mansor et al., 2015). Another study involving several species of babbler identified differing foraging heights and foraging substrates as important mechanisms, allowing multiple species of babbler to co-exist (Mansor & Ramli, 2017). Similar niche partitioning strategy was reported among babblers in Peninsular Malaysia and Borneo (Styring et al., 2016).

The question that arise therefore were (i) what type of arthropods would be available for babblers in the disturbed forests in Pelagus? (ii) do the arthropods also partition their use of space like the babblers do? and (iii) how would the arthropods respond to forest disturbance or environment changes?

The objectives of this chapter were

- 1) to determine which of the site covariates influence the abundance of arthropods,
and
- 2) to examine the temporal and spatial pattern in arthropod abundance.

The hypotheses of this chapter are (i) the abundance of prey groups is affected by the disturbance covariates as shown by babblers in Chapter 3, and (ii) the prey is different, both spatially and temporally, at Pelagus.

4.2 Materials and Methods

There are many ways to collect arthropods, active (A) and passive (P). The former refers to methods in which substantial effort and energy are required during the collection while the latter requires life-history understanding of the targeted species, that needs to match methods used (Upton & Mantle, 2010). Examples of the active method include branch-clipping, sweep-net, aspirator and vacuums, and litter-collection, while passive methods are sticky trap, malaise trap, baited trap and pitfall trap (Capinera, 2010; Upton & Mantle, 2010; Donoso et al., 2013).

Table 4.1 shows the methods used in capturing arthropods in different regions. It indicates that methods used are subject dependant. Different methods adopted to capture different species of arthropods.

Most babblers are known as understorey species, which utilise space on or close to the forest floor, thus the targeted arthropods are mainly those ground dwellers or those near the forest floor. In this study, both the pitfall traps and sticky traps used are passive methods, which saved both time and energy allowing the researcher to focus on mist-netting of birds. The only active method applied was the leaf litter collection which required the researcher to collect dead materials such as leaves and twigs from the forest floor quadrat and packing it into plastic bags (three bags every station). Modified Berlese funnel was then applied to lure prey out from the leaf litter. All captured arthropods were identified to the ordinal or class based on Borror and White (2003); Hill and Abang (2010) and Nasir and Su (2015).

Table 4.1: Methods used in collecting arthropods.

No.	Pre. research	Locality and habitat type	Method (s) used	Arthropods collected
1	Karr & Kimberline (2003)	Shrubs-steppe landscape, Idaho USA, National Engineering and Environmental Laboratory, United State of America	Pitfall trap (P)	A total of 531 species of 140 families under 19 orders. The collected arthropods were Diptera, Hymenoptera, Acarina and Araneida
2	Cole et al.(2016)	Former pasture sites, southern Costa Rica	Extractions of litter (A) Pitfall trap (P)	A total of 4753 arthropod individuals belonging to 302 (morpho) species and 25 orders collected. The main constitution of litter collection was Coleoptera, Hymenoptera, Aranea, while pitfall trap collection consisted mostly of Coleoptera.
3	de Carvalho & Manhaes (2017)	Atlantic secondary forest, south east Brazil	Branch-clipping technique (A) Pitfall trap (P)	Captured more Araneida, Isopoda, Coleoptera, Hemiptera and Hymenoptera by branch-clipping technique Dominanted by Hymenoptera, Diptera, Coleoptera and Orthoptera in pitfall traps
4	Ceresa et al. (2016)	Marshland in Spain	Sweep-net (A)	Collected Aranieda, Coleoptera, Diptera, Hemiptera, Hymenoptera, Orthoptera, Hemiptera, Diptera, Gastropoda, Glomerida, Lepidoptera, Odonata and Thysanoptera.

Table 4.1 continued

5	Lee et al.(2001)	Three primary hill dipterocarp forests, four secondary forest and one oil palm plantation in Johor, Malaysia and Singapore.	Baited trap with three different baits, ie. solutions of honey and sugar, and banana pulp (P)	In total, 45 bee morphospecies belonging to five families, Anthophoridae, Apidae, Colletidae, Halictidae and Megachilidae.
6	Schreven (2013)	National laboratory for peat swamp forest, central Kalimantan, Indonesia	Local-pitcher-plant-liked trap (P)	Target species were ants, Hymenoptera. A total of 3051 worker ants belonging four families, 24 genera and 47 morphospecies captured.
7	Burghouts et al. (1992)	Primary and logged forest in Danum Valley, Sabah, Malaysia	Leaf litter collection	Ants, springtails, spiders, woodlice and mites most abundant litter invertebrates collected. Pseudoscorpions, mites and termites dominant in primary forest whilst beetles, millipedes and cockroaches common in logged forest.
8	Abang & Hill (2006)	Peat swamp forest, Kota Samarahan, Sarawak, Malaysia	Modified Pennsylvanian light trap (P) Sporadic UV light trap (P) Observation (A)	Altogether, 100 families under 15 orders of arthropods collected. Dominant orders with more than four families are Gastropoda, Lepidoptera, Coleoptera, Hymenoptera, Odonata and Diptera.

Table 4.1 continued

9	Pang et al. (2016)	Gunung Serambu, Sarawak, Malaysia	Aerial net (A) Baited trap (P)	Combination of these two methods, 371 individuals comprising 97 species of lepidopteran butterflies recorded.
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4.2.1 Sampling Methods

4.2.1.1 Pitfall Trap

A total of 16 customised traps were set at each station. Each unit of pitfall trap consisted of two polypropylene containers (Brand: Jpack, model: ART no. MS20) of different sizes (Figure 4.1) which one was placed inside another. The diameter and the depth of the inner were 11.0 cm and 4.3 cm, while others were 11.5 cm and 9.4 cm. The bottom of the inner container was cut and removed, and put into the bigger container which creating a funnel that only allowed the entry of insect but not its exit (Corn, 1994). A few holes were made using a hyperdermic needle at the bottom of the outer container in order to allow collected rainwater to flow out during periods of rainfall (Capinera, 2010). Every unit of the trap was sunk into the ground, approximately 0.5 to 1 metre away from the pole that held the net used for capturing the birds. The traps were then covered using a few shortened bamboo-skewers leaving a space between 10–20 cm to allow ground-dwelling arthropods to enter. All traps were collected after 96 hours (4 days) and trapped arthropods preserved in vials containing 1.2 ml of 70% ethanol. Samples were sorted and dry-preserved in a box for later identification with silica gel and naphthalene balls.

4.2.1.2 Sticky Trap

Altogether, 16 sticky traps were applied at each station. Sticky-traps used comprised commercially available adhesive paper (Brand: SELL) that are commonly used to capture flies and prevent them from contaminating food in cafeterias (Figure 4.1). These entrap flying insects. The total surface area of each sticky-trap was 18.5 x 26.5 cm. A small hole was punched at the upper left and right corner of the trap and a nylon string was threaded through it to tie the trap to a tree trunk, at about breast-height level, > 1 m. The

tree trunks chosen were usually within 1 to 3 metre away to the pole so that the trap can easily be seen and located. All sticky traps were collected after four days in the forest, packed and brought back to laboratory (Capinera, 2010). Identification of the insects was directly on the sticky sheet using either magnifying glass for macro arthropods or under a binocular stereoscopic microscope (Motic, BA410 series, China) at magnifications of 10x for the minute ones. There was no attempt to remove the insect from the adhesive sheet, since this would have damaged the arthropods rendering their identification difficult.

4.2.1.3 Modified Berlese Funnel

Leaf litter extraction was done by gathering all the litter fall, including the dead leaves, dead woods, and moss within a subquadrat of 0.5 x 0.5 m² on forest floor into a plastic bag. Three subquadrat 0.5 x 0.5 m² were randomly formed within the quadrats that established each station in Chapter 2

The leaf litter was then brought back to the longhouses for extracting the arthropods. The arthropods were extracted by using the closed-funnel system conceptualised from the Berlese Funnel (Capinera, 2010). The leaf litter was placed in a large plastic funnel (diameter, 22 cm). A bulb (Brand: Philips, model: 100 watts) as the source of light was placed above the plastic funnel and the bottom of the funnel leads into a plastic sample bottle containing water. Aluminium foil was used to cover up the bulb and the funnel in order to prevent it from luring night flying insects to the light source. The other end of the funnel was immersed in water inside a plastic bottle so that any arthropods that escaped from the heat from light source would drown in the water. Drowned arthropods were then collected and preserved in a vial containing 70% ethanol (Figure 4.1) and brought back to the laboratory for identification.

The source of electricity in the longhouses was supplied from a petrol-generator. The operation time was standardised at all stations which bulbs to extract the prey from the leaf litter operated from 1900 to 2300 hours every day.



Figure 4.1: Methods used to capture potential arthropods in Pelagus, Kapit. The pitfall trap used to catch ground dwellers (A). The cover of a sticky trap (B). The modified Berlese Funnel before it was covered by an aluminium foil (C).

4.2.2 Statistical Analysis

4.2.2.1 Influences of Environmental Covariates on Prey Counts

Environmental covariates mentioned in Chapter 2 and 3 were applied to determine the association of the covariates with the arthropod abundance. The covariates were 1) forest type, 2) canopy cover, 3) elevation, 4) proportion of pioneer trees, 5) leaf litter depth, 6) number of pets and 7) humans, and 8) diameter of breast-height and 9) distance. The association between covariates and the abundance of arthropods were tested by GLM in R using package *wiqid*.

4.2.2.2 Spatial Distribution

Chi-square contingency table was used to compare the pooled results from sticky traps set at breast height level (> 1 m above ground) with the combined results from pit fall trap sunk into the soil and leaf litter (0 m) that collect on the ground as both are targeting crawling insect on the forest floor, using the formula below.

$$\Sigma\chi^2 = \frac{(Observed - Expected)^2}{Expected}$$

In addition, the arthropod abundances were also tested in relation to the methods used in capturing them, in R using package cluster (Maechler et al., 2019). The Kruskal Wallis Test was applied to check for difference in the level of disturbance between forest types. Kruskal-Wallis Test was calculated out using in Paleontological Statistics Software Package for Education and Data Analysis (PAST), version 3.23 (2013) (Hammer et al., 2001).

4.2.2.3 Temporal Distribution of Potential Prey

Since the collected data are not normal, the Kruskal-Wallis Test was used to determine if the abundance of arthropods varied in response to the different months of the year. Rarefaction curves were produced, also in Past software, to determine which months associate with prey abundance the most.

4.3 Results

4.3.1 Overall result

The potential prey found from this study comprises four classes, namely Insecta, Arachnida (Ara), Myriapoda (Myr) and Gastropoda (Gas). Thirteen orders belonging to Insecta were sampled. They are Ephemenoptera (Eph), Odonata (Odo), Orthoptera (Ort), Phasmida (Pha), Dermaptera (Der), Dictyoptera (Dic), Isoptera (Iso), Hemiptera (Hemi), Coleoptera (Col), Siphonaptera (Sip), Diptera (Dip), Lepidoptera (Lep) and Hymenoptera (Hym). Figure 4.2 shows the numbers transformed to log of each order from all stations throughout the study period. The numbers of arthropod caught were converted into log number because the differences of the numbers among these groups are large.

Diptera (fly) was the most abundant arthropod, and a total 11,295 individuals caught collectively from the methods used, followed by Hymenoptera (ants, wasps and bees) and Coleoptera (beetles). Orders that were captured around the mean number were Ephemenoptera (mayfly), Orthoptera (grasshopper), Dermaptera (earwig), Dictyoptera (cockroach and mantid), Isoptera (termites), Hemiptera (bug), Lepidoptera (butterfly and moth), Araneae (spider and scorpion) and Myriapoda (centipede and millipede) and caterpillar. Three orders represented by only two individuals were Siphonaptera (flea), Scorpionida (scorpion) and Gastropoda (snail), and two orders with only a single individual caught were Odonata (dragonfly or damselfly) and Phasmida (stick insect). Since the differences among the number of individuals are large, they were, thus they are transformed to $\log_{10}$ data in order to fit into the graph and for regression coefficient (Ives, 2015).

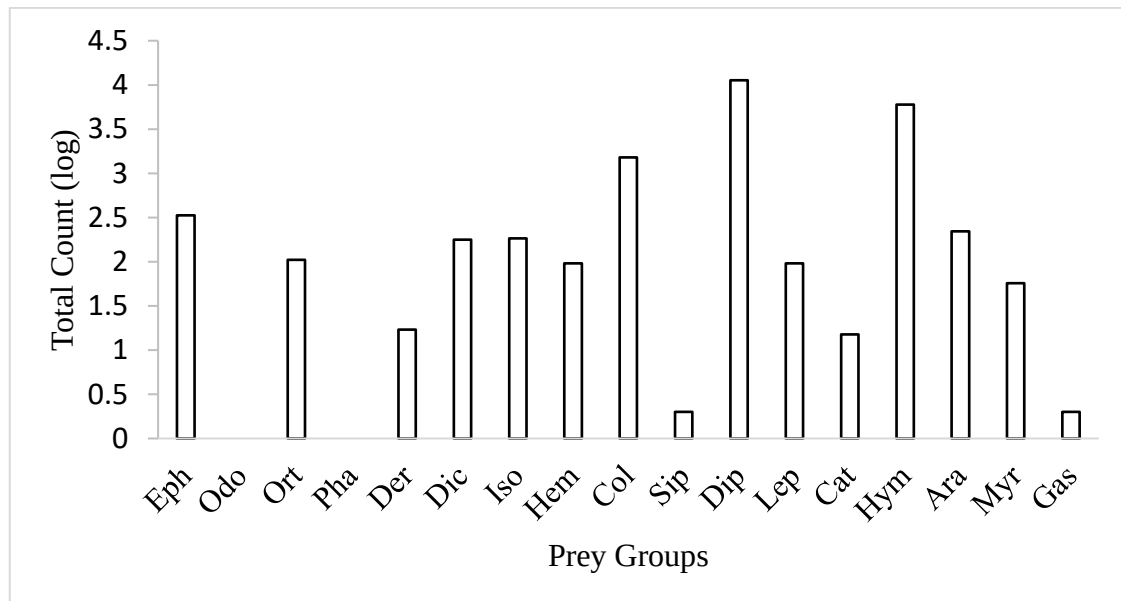


Figure 4.2: Counts of prey groups sampled during the study periods.

4.3.2 Influences of Environmental Covariates on Prey Counts

Of all covariates, canopy cover was the best models to describe the abundance of the arthropods obtained from this study as the AIC value is the lowest among all (Table 4.2). The value reading as 1 in the column model weight (Model Wt) shown in the table indicates that canopy cover has the most influence on arthropod counts. Figure 4.3 indicates that arthropod count is negatively correlated to the canopy cover (r^2 value = 0.1575). The larger canopy cover is, the lower numbers of arthropods recovered.

Table 4.2: GLM results showing the influence of the covariates on arthropod abundance.

	df	AIC	Delta	ModelLik	ModelWt
glm.can	2	2449.862	0	1	1
glm.ft	2	3120.956	671.094	0	0
glm.ele	2	3135.923	686.062	0	0
glm.tp	2	3156.968	707.107	0	0
glm.ll	2	3267.722	817.861	0	0
glm.pet	2	3296.432	846.57	0	0
glm.man	2	3296.726	846.865	0	0
glm.dbh	2	3296.758	846.896	0	0
glm.dist	2	3296.809	846.947	0	0

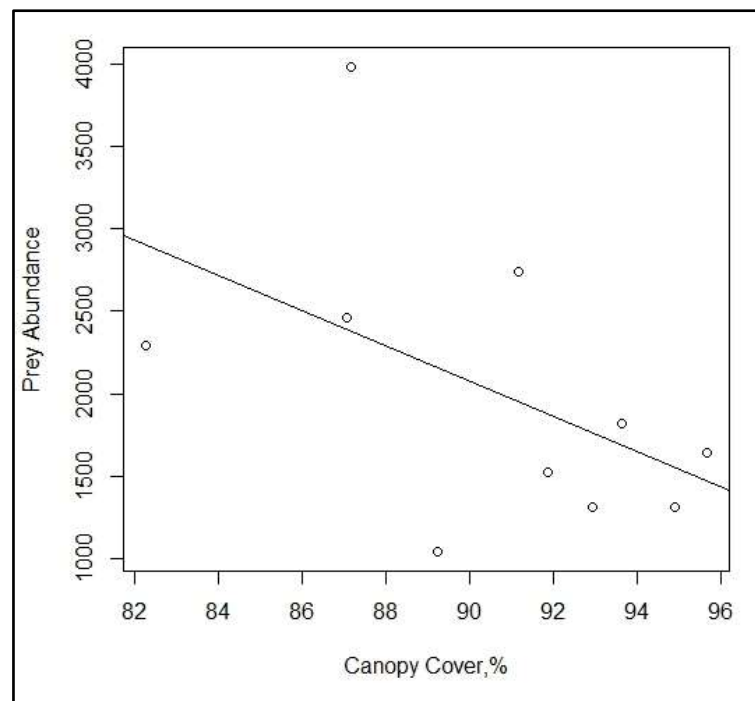


Figure 4.3: The correlation between babbler prey count and canopy cover at each sampled station in Pelagus, Kapit

4.3.3 Vertical and Horizontal Distribution of Potential Prey in Pelagus

A total of 15 prey groups were recovered by sticky traps and pitfall traps and eight groups were collected from the leaf litter. Diptera predominated, followed by Hymenoptera and Coleoptera. Prey groups with the least number captures are Siphonaptera, Gastropoda, Odonata and Phasmida.

The number of prey groups captured by using sticky traps was far greater than the other two methods combined (Table 4.3). This implies the potential prey at all stations more at the height at breast height level, > 1 m in the forest. In addition to Dipetera, Hymenoptera, and Coleoptera which were captured in greater number at breast height level by sticky traps than on the ground, Odonata and Phasmida were captured only by sticky traps. This indicates their utilisation in upper space more than forest floor. In contrast, Siphonaptera and Gastropod were only trapped by pitfall traps implies that they are ground dwellers, alongside Ephemnoptera and Myriapoda. The result obtained from Chi-squared (χ^2) test shows that the collective number of all prey groups caught on the trunk at breast height level is significantly higher than those on the ground.

Table 4.3: List of potential prey captured using three different methods in Pelagus, Kapit.

Prey group	Order	Breast Height (>1 m)	Ground (0 m)	
		Sticky trap	Pitfall trap	Leaf litter
Insecta				
	Ephemenoptera	4	331	0
	Odonata	1	0	0
	Orthoptera	90	15	0
	Phasmida	1	0	0
	Dermaptera	10	7	0
	Dictyoptera (Dic)	160	14	3
	Isoptera (Iso)	166	15	3
	Hemiptera (Hem)	85	10	1
	Coleoptera (Col)	1461	47	12
	Siphonaptera (Sip)	0	2	0
	Diptera (Dip)	11287	8	0
	Lepidoptera (Lep)	94	2	0
	Hymenoptera (Hym)	5277	675	64
	Caterpillar	11	2	4
Arachnida		149	62	9
Myriapoda		11	40	8
Gastropoda		0	2	0
Total		18807	1232	104
χ^2	df =3, χ^2 > 16.266, significance, p < 0.01			

Sticky trapping is an effective method for capturing flying insects, such as Orthoptera, Odonata, Lepidoptera and Diptera. It also effectively samples terrestrial prey group in the current study, as they found Dictyoptera, Isoptera, Hemiptera, Coleoptera, Hymenoptera and Araneida ascending from forest forests to tree trunks. A greater number of ground-moving species such as tiny spiders and scorpions (Arachnida), Myriapoda and Gastropoda were found in pitfall trap and leaf litter extraction. In the context of this study, some stations were adjacent to rivers and thus, the ephemeropterans were pitfall-trapped.

Despite pitfall trap and leaf litter extraction targeting similar arthropods, the combination of sticky trap and pitfall trap captured similar orders from all 10 sites (Figure 4.4). Prey groups formed three clusters.

The clumped zone shows that many prey groups from different sites had equal chance to be captured by all three methods, such as the Isoptera, Hemiptera, Dictyoptera and Arachneida. Symbols ‘+’ that are outside the clump zone refer to prey groups, such as Ephemenoptera, Siphonaptera and Gastropoda that were captured mainly by pitfall traps. Symbols ‘Δ’ indicate Diptera, Hymenoptera and Coleoptera that were caught mostly by sticky traps.

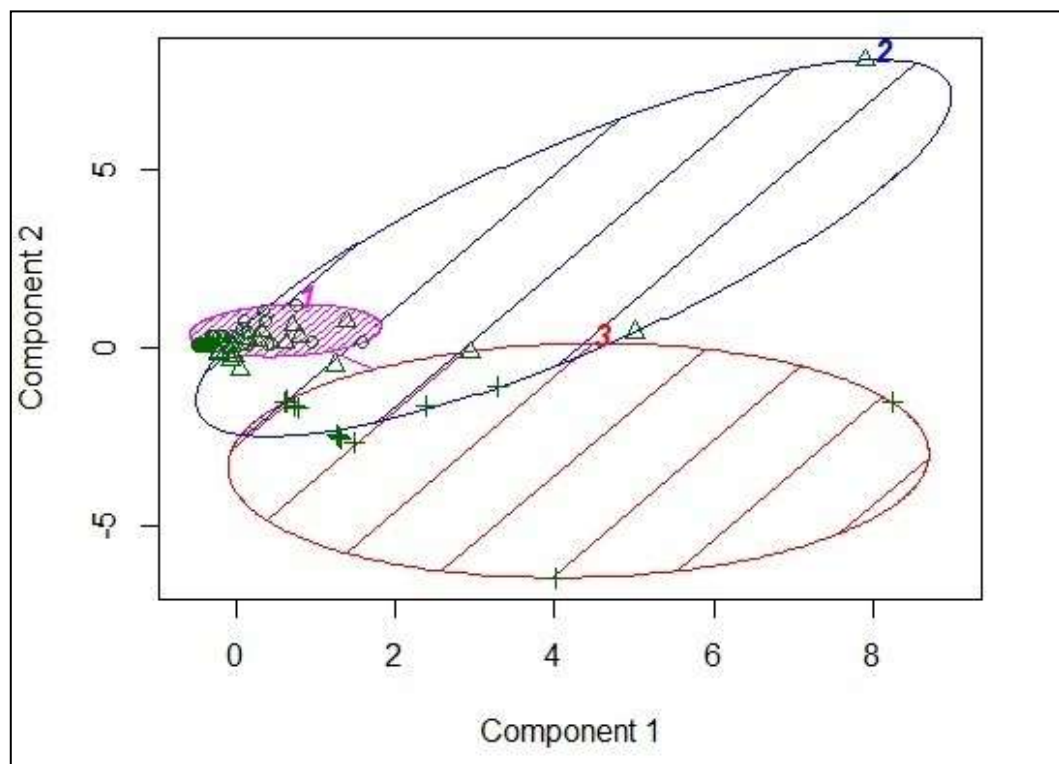


Figure 4.4: Cluster analysis on babbler prey abundance in relation to the methods used for capturing them at Pelagus, Kapit. Δ represents prey groups that caught by sticky traps, + represents those by pitfall traps and o represents those collected in leaf litter.

In comparing the prey count horizontally among stations in this study, PR500 had the highest count in which the dipterans contributed the most. It follows in a descending order by B100, PR100, PR1000, B1000, PL500, B500, PL100, PL1000 and PNP, where hymenopterans and dipterans were dominant in the stations. Coleopterans were the third largest group of insects captured after the dipterans and hymenopterans (Table 4.4).

Nine orders of Insecta, Myriapoda and Arachnida were captured at all stations. Insects included Ephemeroptera, Orthoptera, Dictyoptera, Isoptera, Hemiptera, Coleoptera, Diptera, Lepidoptera (adults) and Hymenoptera.

The orders Odonata and Phasmida were represented by one individual, while Siphonoptera, had two individuals. Gastropoda was also represented by two individuals. These four groups were the least often captured in this study. Odonata was caught once on a sticky trap and only at B500, while Phasmida at PR500, both by sticky traps. Gastropoda was captured by pitfall traps at B500 and PR100. Siphonoptera was found only at PNP.

Prey abundance tested collectively by forest types, secondary forest versus agroforest ($t = 2$, $n = 4$) using a Kruskal-Wallis Test. The p values show that the comparison on prey abundance between forest types ($p = 0.8852$) was insignificant.

Table 4.4: Distributions of captured arthropods at stations in Pelagus, Kapit.

Class	Order	PNP	PL100	PL500	PL1000	B100	B500	B1000	PR100	PR500	PR1000
Insecta	Eph	32	11	23	24	34	74	51	21	31	34
	Odo	0	0	0	0	0	1	0	0	0	0
	Ort	11	12	10	10	13	8	14	4	7	16
	Pha	0	0	0	0	0	0	0	0	1	0
	Der	0	0	3	1	2	3	1	2	3	2
	Dic	9	18	12	15	27	23	22	31	8	12
	Iso	10	6	2	36	10	14	8	17	75	6
	Hem	7	9	6	20	6	10	13	4	17	4
	Col	170	158	144	175	99	196	132	122	131	192
	Sip	2	0	0	0	0	0	0	0	0	0
	Dip	329	803	1186	739	1212	736	1271	1179	3015	825
	Lep	6	11	5	7	18	6	24	6	1	12
	Lep (C)	0	2	0	3	4	2	0	1	1	2
	Hym	448	252	213	251	1295	424	266	1054	664	1146
Arachnida		10	26	27	30	15	25	17	15	22	34
Myriapoda		10	7	9	4	1	3	2	7	5	9
Gastropoda		0	0	0	0	0	1	0	1	0	0
Total		1044	1315	1640	1315	2736	1526	1821	2464	3981	2294

4.3.4 Temporal Distribution of Babbler Potential Prey in Pelagus

A marked temporal pattern is shown on arthropod abundance in Pelagus. Period with the lowest rainfall, August 2016 encountered the highest arthropods count, followed by November 2016, December 2015 – January 2016 and the least in the period with the highest rainfall between March – April 2016 (Table 4.5). Most arthropods were recorded in multiple periods, except the Siphonaptera which was recorded only in December 2015 – January 2016 and Phasmida and Odonata which were recorded only during November 2016. The straight line with r^2 value 0.8281 reveals that the collective prey counts and the rainfall during the sampling periods were negatively correlated (Figure 4.5). However, the results obtained from Kruskal-Wallis test on with four treatments (t) and 10 sampling stations (n) showed that the abundance of prey did not vary significantly between sampling periods despite there was variation in rainfall (p-value is 0.2168).

Table 4.5: Pooled results on potential prey captured by three different methods used between December 2015 – November 2016 in Pelagus.

Group	Order	Sampling period			
		Dec 15 – Jan 16	Mar – Apr 16	Aug 16	Nov 16
Insecta	Ephemenoptera	46	154	67	68
	Odonata	0	0	0	1
	Orthoptera	31	24	32	18
	Phasmida	0	0	0	1
	Dermaptera	6	0	9	2
	Dictyoptera	31	44	35	67
	Isoptera	53	66	35	30
	Hemiptera	29	25	18	24
	Coleoptera	407	304	479	330
	Siphonaptera	2	0	0	0
	Diptera	3460	2482	4201	1152
	Lepidoptera	21	21	28	26
	Hymenoptera	743	969	1131	3173
Arachnida		81	64	37	38
Myriapoda		7	8	17	27
Gastropoda		0	0	1	1
Caterpillar		5	6	2	4

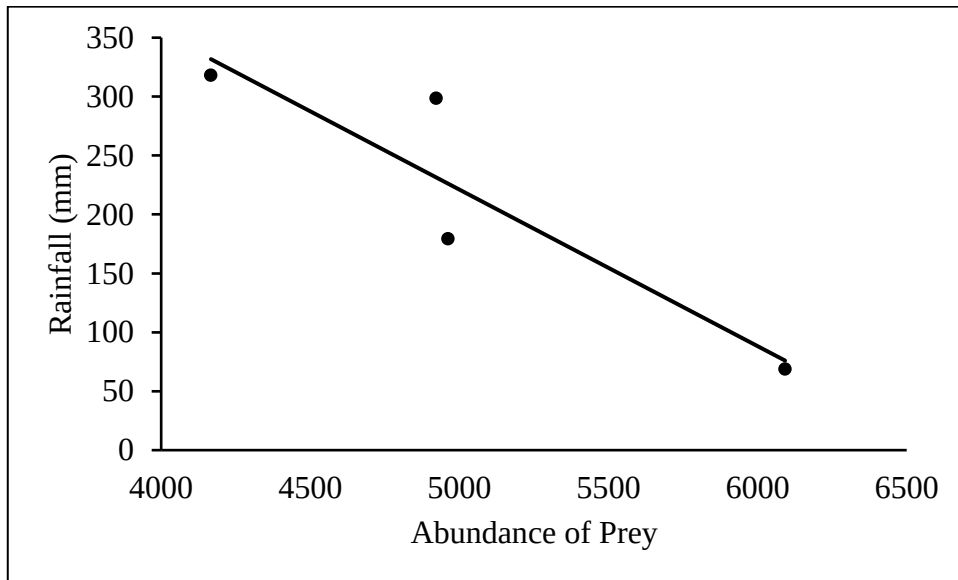


Figure 4.5: The abundance of prey of babblers captured in Pelagus in relation to the rainfalls (mm) in four sampling periods.

The rarefaction curve shows that the collective abundance of potential prey from all stations was highest during August 2016 followed by November 2016, and December 2015 – January 2016. The least number of prey were collected during the wettest period, in March – April 2016 (Figure 4.6).

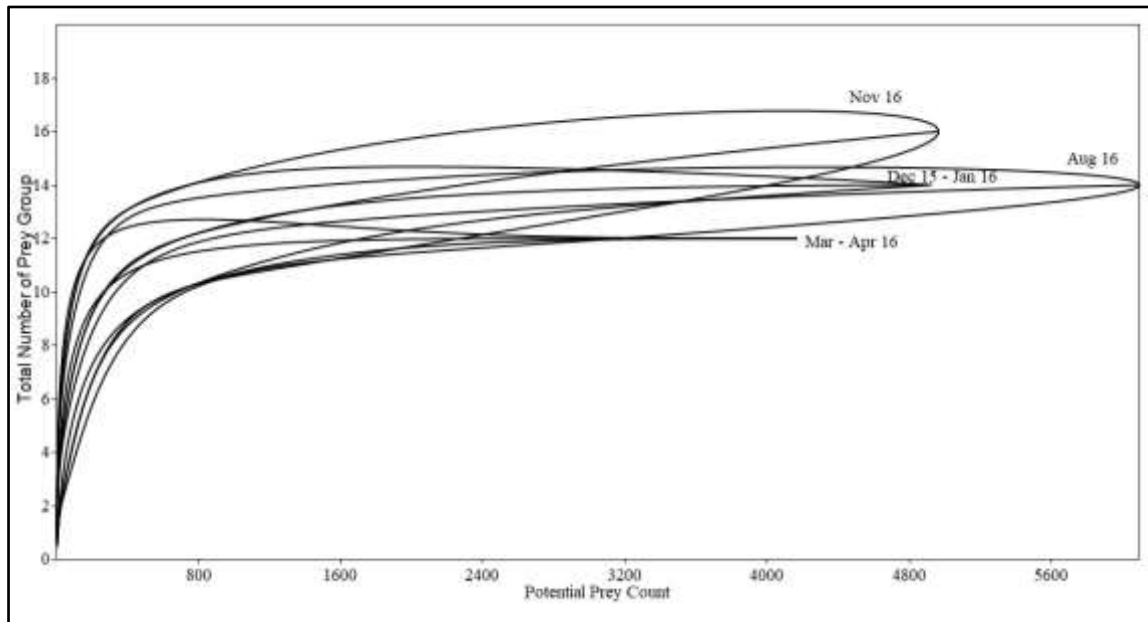


Figure 4.6: Rarefaction curves representing the relationship between potential prey count for babblers (accumulated individual number on x-axis) and the number of prey groups (y-axis) at Pelagus, Kapit.

4.4 Discussion

Despite Coleoptera being the largest numerical group among insects in Borneo (Hill and Abang, 2010), Diptera and Hymenoptera were the most collected in this study. This could be due to the methods applied which were efficient in capturing these two groups. In fact, the sticky traps had scent that can lure the dipterans. Flying insects such as wasps and bees (Hymenoptera) were reported to be diverse and abundant in both primary

and secondary forest (Lee et al., 2001) could be good reason for their high occurrence in the study.

Of all disturbance attributes that could possibly affect the arthropod abundance, the canopy cover influenced the prey the most. The smaller the canopy cover is, the greater number of prey collected under it. In contrast, Savitha et al. (2008) found that the number of some common species and rare species in Bangalore, India was higher in an area with smaller canopy cover than area with a larger one. The ants in that study were mostly arboreal, staying in their preferred trees, while those collected in this study move on the ground mostly or close to the ground. Large canopy gaps allow penetration of sunlight which warm up the understorey area making the prey highly mobile, thus increasing their trapping probability.

The litter invertebrate study carried out by Burghouts et al. (1992) reported that beetles (Coleoptera), millipedes (Myriapoda) and cockroaches (Blattodea) were abundant in logged forest, but pseudoscorpions mites (Arachnida) and termites (Isoptera) preferred leaf litter and fine root that were found more in primary forest. In this study, least number of prey groups were trapped in PNP, compared to agroforest, secondary forest and logged forest behind the longhouses as prey groups likely prefer the latter vegetation. The two stations with the highest count, contributed by Dipterans, were PR500 which was covered by secondary forest while at B100 which was covered by agroforest, Hymenoptera accounted the most. Their occurrence in disturbed areas suggests they were capable of acclimatising to the changes that occurred in the surroundings (Savitha et al., 2008).

Many methods are available in determining the diversity of arthropods in the wild (Capinera, 2010; Upton and Mantle, 2010). Pitfall traps, sticky traps and leaf litter

extraction using modified Berlese Funnel were selected for the purpose of determining potential arthropod prey of babblers due to babblers' occurrence that is confined in the understorey as shown in Chapter 3 in this study and also by previous researches (Mansor & Ramli, 2017; Mansor et al., 2015; Pang et al., 2017; Styring et al., 2016).

Results in this chapter show that the flying insects such as Odonata, Orthoptera, Phasmida, Coleoptera, Diptera Lepidoptera and non-Formicids Hymenopterans such as bees and wasps are often captured by sticky traps as they are moving off the ground at breast height level in the forest.

Ants (Formicidae – Hymenoptera) being a ground dweller, are vulnerable to capture by sticky traps that were tied on the tree trunk, as ant colonies move up to the trees from the ground (Soares et al., 2013). Arboreal ants are found in tropical forests and agroforest in which they are numerically abundant, competitive and also aggressive in protecting their territories (Leston, 1973). Ants tend to move in large number. This explains why the yield from sticky traps surpassed the other two (combined) significantly. Ants fall into the pitfall trap easily too, hence they also were dominant in the catch of pitfall traps. For instance, the *Camponotus gigas* (giant ants) were only recorded in pitfall traps in this study, but were not abundant because they are solitary foragers and do not practice colonial movement like other species (Tillberg et al., 2014).

Despite possessing a pair of advance wings (Hill & Abang, 2010), coleopterans are sometimes ground-dwellers. Not only do they live on the ground but also move slowly on the forest floor (Pang et al., 2018). Like hymenopterans, coleopterans were captured at breast height level as well as on the ground.

Of all prey groups recorded in this study, those that crawl and dwell on the ground or forest floor, including Ephemeroptera, Myriapoda and Gastropoda, were caught mainly by pitfall traps.

Prey count peaked in August 2016 and was the least in March – April 2016 likely resulting from their occurrences associated with rainfall. Both dipterans and coleopterans, which constitute the greatest part of the capture numbers, are likely avoiding rain. On the contrary, Ephemeropterans were caught most March – April 2016. It is reasonable that being aquatic animal, the nymphs of ephemonepteran contribute to most catch during high volume of rainfall. The period with increasing humidity and moisture may promote the mobility of the ephemenopteran.

Without associating with rainfall, hymenopterans were trapped the most in August 2016. It could due to the migration of ants from the soil vertically up tree trunks, as suggested by Soares et al. (2013) and captured on sticky traps.

The fluctuation of prey count in relation to season could be related to breeding season, as reported by Murakami (2002). Lepidopterans lay eggs on specific host plants (Corbet and Pendlebury, 1992). The occurrence of caterpillars on forest floor and canopy at different times of the year indicating there are temporal pattern of its food resources. Other study found that the adult lepidopteran was abundant in primary forest than in secondary forest during the wet season (September – February) but shows the opposite trend during the dry season (March – August) (Hamer et al., 2005). Despite other researchers showing marked seasonal pattern, the current study did not showd marked variation in numbers of captured lepidopterans across the four sampling periods spanning 12 months. Perhaps the lack of pronounced season in the study mean that potential food

sources for lepidopterans are aseasonal, and therefore the lepidopterans themselves are also aseasonal.

4.5 Conclusion

A total of 17 prey groups were recorded in this study, using three different techniques which are sticky traps, pitfall traps and leaf litter collection. Diptera was the most abundant among prey groups, followed by Hymenoptera and Coleoptera.

Canopy cover was the most influential covariate that affected the abundance of arthropods. The greater the canopy cover, the lower was the prey densities. Sticky traps set on tree trunks were the most efficient methods in capturing the group, giving rise to significantly higher number of prey count compared to pitfall traps and leaf litter collection combined. This shows that most prey move at breast height level, > 1 m off ground in the forest. Prey was negatively correlated to precipitation and the results show that they were most abundant in August 2015, when the rainfall was low and least in March – April 2015 when rainfall was high.

Arthropods outclass many other phyla under the kingdom of animal in their numerical abundance and species diversity. They are highly persistent and resilient to the changes in environment, and thus rapidly recover their population in a degraded forest.

CHAPTER 5

THE COMPOSITION BABBLER DIETS AND NUTRIENT CONTENTS OF POTENTIAL PREY

5.1 Introduction

5.1.1 Composition of Insectivorous Bird Diets

Considering the occurrence of animals in an area is highly associated with food resources and availability, the feeding guild shown in Table 3.2 (Chapter 3) indicates the grouping of avifaunal assemblages based on what they feed on in the sampling areas. For example, an insectivorous bird diet is comprised mainly of arthropods, including insects, spiders and scorpions. Insectivorous birds do not eat all insect groups but are restricted to certain orders. In addition, some birds even shift their diets from arthropods to fruits when availability of their obligate food resources is low (Sherry et al., 2016).

Avian diets are globally wide studied. In the temperate countries, a study on the diet of *Thryothorus ludovicianus* (Carolina Wren), *Wilsonia citrina* (Hooded Warbler), *Oporornis formosus* (Kentucky Warbler) and *Vireo griseus* (White-eyed Vireo) in the forests of Barnwell Country, southern California, USA, reveal that coleopterans and hemipterans were consumed by the birds that foraged on ground and in the foliage, in both spring and fall migration period, without any sign of shifting their diets (Moorman et al., 2007).

A study conducted in Spain of two sympatric warblers *Acrocephalus medianopogon* (Moustached Warblers) and *A. scirpaceus* (Reed Warblers) showed they consumed Coleoptera, Hymenoptera and Araneida. Despite overlapping in food resources, these two

species avoid competition by having different breeding periods, *A. medanopogon* breeds six weeks earlier than *A. scirpaceus*, thus food demand is also at a different time (Ceresa et al., 2016).

Mizutani and Hijii (2002) studied the foraging behaviour and prey preference of two species of Tits, *P. major* (Great Tit) and *P. varius* (Japanese Tit) in central Japan. *P. major* was reported to forage between the foliage of deciduous broad-leaved trees, while *P. varius* fed on those broad-leaved leaves which higher where evergreen *Cryptomerica japonica* was dominant, but lower where the deciduous tree, *Larix kaempferi* was abundant. Nestling *P. varius* predominantly consumed caterpillars while those of *P. major* fed on a wider range of arthropods, consisting of caterpillar, orthopterans and spiders.

Gaiotti and Pinho (2013) demonstrated that *Cnemotriccus fuscatus* (Fuscous Flycatcher), is an exclusive insect-eater in Cambrazal, South America. Its diet comprises mainly of ants and beetles. The same species was reported as omnivores, feeding on both beetles and plant seed in other localities in Cordelir.

Unlike many insectivorous birds that have been reported to favour Coleoptera, two understorey species in montane rain forest in south eastern Brazil, *Canopophaga lineata* and *Myiothlypis leucoblephara* feed predominantly on Formicidae (ants) (Manhaes et al., 2015).

Sherry et al. (2016) demonstrated that warblers in Jamaican are opportunistic feeders, but partition their diet according to the mobility of prey found. Their diet comprised mainly coffee berry borers and coleopterans, although the *Setophaga ruticilla* (American Redstarts) fed more on prey with greater mobility, while *S. americana* (Northern Parulas) consumed sessile prey.

Wong (1986) reported that the availability of food resources, such as flowers and fruits in the forest, particularly in understorey, were rarely available. These resources were even lower in regenerating forests than in primary ones. Understory birds at the Pasoh Forest Reserve, Negeri Sembilan, in Peninsular Malaysia, feed on arthropods. During periods when numbers of arthropods are low, birds would shift their diets to grain or fruits (Wong, 1986). *Polioptila c. californica* (California Gnatcatchers) were found primarily consuming Homoptera, followed by Araneae, Coleoptera, Orthoptera, Diptera, Lepidoptera, Hemiptera and Hymenoptera (Burger et al., 1999).

A study in Sarawak, Borneo also found that coleopterans were the main food resources for birds of the families Corvidae, Eurylaimidae, Muscicapidae, Pycnonotidae, Timaliidae, Pellorneidae and Monarchidae, which were captured in oil palm plantations, secondary forests and primary forests (Pang et al., 2018).

Pycnonotus goiavier (Yellow-vented Bulbul), a dominant bird species in an oil palm plantation located in Betong District, Sarawak, was found to feed mainly on coleopterans pollinating weevil and members of the homopteran (Amit et al., 2015). The preference for the pollinating weevil is worrying, because it may affect the population of pollinators, and therefore palm fruit formation.

5.1.2 Prey Composition in the Diets of Babblers

Babblers are known to be insectivorous (Zakaria et al., 2005; Gray et al., 2007; Zakaria & Rajpar, 2010; Azman et al., 2011; Beaudrot et al., 2013; Pang et al., 2017; Mansor et al., 2018), except the Bornean Pied Shrike-babbler, which is an omnivore (Beaudrot et al., 2013).

A study conducted on the diets of Jungle Babbler in the district of Jammu, India, found that this species has a wide dietary spectrum (Anthal & Sahi, 2013). It consumes primarily arthropods, such as Orthoptera (grasshoppers), Coleoptera (beetles), Lepidoptera (moths and butterflies) and caterpillars. Arthropods that were less preferred were Isoptera (termites), Odonata (dragonflies), Hymenoptera (ants, bees and wasps), Dictyoptera (cockroaches and mantis), Hemiptera (bugs) and Araneida (spiders). During the period when arthropods are scarce, babblers were reported to shift their diets to fruits, such as wild berries, nectar, rice grain and maize.

Turdoides squamiceps (Arabian Babbler) in Shezaf Nature Reserve at Hatzeva, experienced great changes in temperature during summer and winter with average daily temperature of 38°C and 9°C, respectively. Under these circumstances, the adaptive babblers shift their diets. During summer, they feed more on insects that contain high energy, while in winter, they opted for moist fruits. In general, this species has a comparatively low field metabolic rate than other avian species, but it is similar to that of other birds in the desert (Anava et al., 2000).

Seven sympatric babbler species, GHB, CWB, RWB, SCB, MB, HB and STB were reported to inhabit lowland dipterocarp forest and agroforest at Bau, Sarawak. Prey consumed mainly consisted of Coleoptera (40%), Hymenoptera (18.67%), Orthoptera (13.33%), Arachnida (9.33%), Diptera (8%), and other unidentified items (Zaman, 2012).

Mansor et al. (2018) demonstrated that 12 sympatric babblers (BCB, WCB, FB, MB, SCaB, SCB, RCB, GHB, BTB, CRB and FBTB) in Krau Wildlife Reserve, Peninsular Malaysia consumed a wide array of prey. Coleoptera, although consumed predominantly by babblers, especially the MB, they also prey on other arthropods such as

Hymenoptera, Blattodea and Arachnida. Low food overlap ($p = 0.070$) among babblers indicates low interspecies competition for food. The result also shows that the prey items consumed did not corresponding to body mass of babblers.

Diet and niche breath among sympatric babbler species may be similar due to locality but also could be different due to species' survival requirements. Babblers, in the current study, are mainly ground-based; some are confined to understorey and partially arboreal. Previous studies revealed the prey that consumed by babblers, but the prey preference in disturbed habitat with multi-covariates remain unclear. Their diets shall be elucidated at Pelagus.

5.1.3 Relationships Between Bird Predators and Arthropod Prey

Bornean insectivorous babblers occur over a wide variety of habitats (Sheldon et al., 2010; Razak et al., 2015; Styring et al., 2016; Ramji et al., 2016; Pang, et al., 2017; Pang et al., 2018). Their presence at the lower strata of the forest (Mansor et al., 2015; Pang et al., 2017; Mansor & Ramli, 2017), is probably associated with the availability of food resources. Thus, it is hypothesised that there is a positive relationship between the abundance of babblers and their prey.

In a similar study on sizes, Leyequi  n et al. (2006) demonstrated that sympatric birds become competitive when the body masses are similar. The greater difference between the body masses, the lower the competition in foraging. Nevertheless, body mass and competition strength did not significantly influence foraging guilds. The study concluded that coexistence in a community is promoted if the species and individuals of bird possess different body masses.

In addition to the aspect of prey availability, preferences or options on diets may be varied due to the nutrient requirements at different life stages, such as age, growth, body-size, egg and gamete production and health maintenance (Murphy, 1996). Other studies found that prey size preference was positively related to the predator body size within the same feeding niche. For example, a study in Brazil showed that *Conopophagidae lineata* (Rufous Gnateater), with a larger body size, fed on larger beetles (Coleoptera) and ants (Formicidae), while *Myiothlypis leucoblephera* (White-browed Warbler) consumed smaller ones within the same type (Manhaes et al., 2015).

The body size of babblers was used as a variable in determining the relationships between the effect of logging and trophic position (Keith et al., 2015). Large ground-feeding babblers are more adversely affected by logging than smaller understory-feeding babblers. The information in respect to the relationship between the sizes of predators and prey is lacking. It is hypothesised that 1) the size of predator is correlated to that of its prey, and 2) prey-selection is based on nutrient requirements.

Sam et al. (2017) demonstrated that the body size of 999 individuals from 99 insectivorous bird species in Papua New Guinea had a positive correlation with that of arthropods they consumed. The most exploited arthropod groups were, in order, Coleoptera, Araneae, Hymenoptera, and Lepidoptera. Selectivity indexes revealed that birds opportunistically fed on arthropod, reflecting the spatial pattern of arthropod abundance to which the birds were exposed.

5.1.4 Methods Used to Study Avifaunal Diets

Table 5.1 shows the six most common methods used to study avifaunal diets. Direct observation requires a pair of binoculars to observe the targeted subjects in their

natural habitat. No handling of bird is required and thus the technique is stress and mortality free. Nevertheless, the drawbacks of this method are that identification may be difficult for small birds that are of similar morphology and identification of the prey, especially small ones, could be imprecise in the thick foliage. The excrements or faeces used in Orlowski and Karg (2013) were collectively obtained from individuals of syntopic species. Other techniques include retention of each bird in a single bag with as little stress to the birds as possible, and after the bird defecate, the faeces were examined. Additionally, the mortality is minimum, but the prey items can be hard to identify because it has undergone digestive processes (Rosenber & Cooper, 1990; Moorman et al., 2007).

Despite the differences in techniques, the pros and cons of examining stomach flushing and regurgitated sample to study bird diets were similar. Identification of prey is easier with higher chances in getting intact prey. The disadvantage is the risk of mortality on account of stress and if improper volumes and concentrations of solution are applied. Rosenberg and Cooper (1990) applied warm water for flushing which was considered more comfortable for birds and suggested regurgitation be conducted on-site and immediately often food items are ingested. Stomach content are be considered if bird died accidentally in the field.

In additional to the methods shown in the table above, stable isotope techniques have been used to study the trophic position of babblers (Hamer et al., 2015), but requires sophisticated equipment that is not always available in developing countries.

Table 5.1: Techniques used to study the diets of birds.

Methods	Direct observation	Examination of excrements	Examination of stomach flushing	Examination of regurgitated sample	Stomach content
Citation	Chapman & Rosenberg (1991) Orlowski & Karg (2013) Mohd-Azlan et al., (2014)	Parrish et al. (1994) Baker-Gabb (1988) Burger et al. (1999) Moorman et al. (2007) Orlowski & Karg (2013) Sainz-Borgo (2016) Nuhličková et al. (2016)	Gionfriddo et al. (1995) Barrett et al. (2007) Fijn et al. (2012) Manore et al. (2017)	Poulin et al. (1994) Carlisle & Holberton (2006) Mallet-Rodrigues (2001) Sherry et al. (2016) Pang et al. (2017)	Amit et al. (2015) Luo et al. (2015) Siqueira et al. (2015)
Brief description of technique	Binoculars used Observation from distant point on what birds were feeding on	Collection from clean cotton bags in which captured birds were kept.	Tiny tube connected to syringe with water inserted into crop, stomach or gizzard of birds.	Administration of tartar emetic in right amount to targeted subject through a catheter	Removal of gizzard from the dead bird Investigation of the consumed items in the gizzard.

Table 5.1 continued

			Water flushes stomach contents out.	Birds allowed to rest for at least 10 minutes. Collection of regurgitated items.	
Advantage(s)	No body contacts, stress and mortality free	Little stress	High chance of getting intact prey	High chance of getting intact prey. Identification easier	All consumed item in stomach retrievable.
Disadvantage(s)	Identification difficult for small birds with similar morphology Imprecise identification of diets in thick foliage	Prey items highly fragmented No guarantee of excrements obtained Chances of getting intact body of prey low	Stressful for smaller birds	Lethal if improper volume and concentration administrated.	Applicable only for dead birds.

5.1.5 Nutrient Content of Potential Prey Items

Fundamental nutrients include energy, protein, minerals, vitamins, fatty acid and fibre (Murphy, 1996). Studies on the diets of pheasants, quail, ducks, geese and turkeys show that the requirement for each nutrient varies accordingly to the physiological status. Energy (11.5–12.5 kJ ME/g) and protein (16.0–30.0 %) are needed the most during early growth stages, lower during egg production (11.3–12.1 kJ ME/g and 14.0–24.0 %) and the least to maintain non-breeding adult (8.0–14.0%). The same amount of fatty acids are required during growth and egg production (1.0–1.5%), but lower than 1.0% is required for maintenance. Calcium and phosphorus requirements are higher for egg production (1.9–3.8% and 0.6–1.1%, respectively), lower for growth (0.4–1.7% and 0.3–1.0%) and the least for maintenance (0.44% and 0.21%). Birds obtained all these nutrients from their food and hence the nutrient content of their food play an equally important role as food availability in ensuring nutrient requirement are met.

Studies on arthropod nutrients contents are important as they are not only food resources for wildlife (Capinera, 2010; Murphy, 1996) but also to humans and their livestock (Tomberlin et al., 2018). Arthropods are known as energy-rich and protein-rich diet (Murphy, 1996; Anava et al., 2000; Kouřimská & Adámková, 2016; Firoozfar et al., 2016) that supply the needs of wild birds, bats and small mammals. Nevertheless, nutrients obtained from or supplied by arthropods may vary according to individual, species or locality. This variation is the basis for resource partitioning and coexistence that occur in a forest with multispecies avian communities.

At least 27 species of 11 orders of arthropods have been analysed for their nutrient contents (Table 5.2). *Oecophylla smaragdina*, a hymenopteran, provides the most energy,

1272 kcal/100g. Blattodea of Dictyoptera contained the highest amount of inorganic matter in ashes (8.43%). Insects are known to be rich in protein but Araneae (spiders) is reported to contain the highest amount of protein, (76.25%). Adult arthropods have maximum 20% of crude fat, while the larvae of *Zophobas atratus* (Coleoptera) can have crude fat three times higher than that of adult (60%). Both *Macrotermes bellicosus* of Isoptera and *Analeptestri fasciata* of Coleoptera have the highest amount of phosphorus amongst all (1.36 mg/g).

Arthropod groups that occur frequently in the diet of insectivorous birds have higher energy, crude protein content and consistently higher concentration of seven microminerals (Razeng & Watson, 2015). This suggests that birds may select prey based on nutritional quality but how this knowledge is passed to them, whether genetically from parents to offspring or from prior eating experience, is not known.

Table 5.2: The nutritive values of arthropods (The superscripts represent source of references).

Order	Others	Energy kcal/100g	Ash %	Crude protein %	Crude fat %	Phosphorus mg/100 g
Coleoptera ⁱ	<i>Analeptestri fasciata</i>	-	4.21	29.62	18.39	136.4
Coleoptera ⁱ	<i>Rhynchophorus phoenicis</i>	-	2.70	28.42	31.40	-
Coleoptera ⁱ	<i>Oryctes boas</i>	-	1.50	26.0	1.50	-
Coleoptera ⁱⁱ	-	-	-	23–66	-	-
Coleoptera ^{iii, vi}	<i>Tenebrio molitor</i>	138 – 206	-	24.955 ± 0.699	6.096 ± 0.37	-
Coleoptera ^v	<i>Tenebrio molitor</i> (L)	-	-	-	36	-
Coleoptera ^v	<i>Zophobas atratus</i> (L)	-	-	-	60	-
Coleoptera ^{vii}	<i>Holotrichia parallela</i>	-	5.53 ± 0.23	70.57 ± 0.12	3.76 ± 0.53	-
Coleoptera ^{viii}	-	-	8.21	73.75	12.00	53.71
Orthoptera ⁱ	<i>Brachytrypes</i> spp.	-	1.82	6.25	2.34	126.9
Orthoptera ⁱ	<i>Cytacanthacrisaeruginosus</i> <i>unicolor</i>	-	2.10	12.1	3.50	100.2
Orthoptera ⁱ	<i>Zonocerus variegatus</i>	-	1.20	26.80	3.80	131.2
Orthoptera ⁱⁱ	-	-	-	23–65	-	-
Orthoptera ⁱⁱⁱ	<i>Acheta domesticus</i>	-	-	15.684 ± 0.872	7.308 ± 0.794	-
Orthoptera ^{v, vi}	<i>Locusta migratoria</i>	179	-	-	13	-
Orthoptera ^v	<i>Gryllus assimilis</i>	-	-	-	34	-
Orthoptera ^{vi}	<i>Chortoicetes terminifera</i>	499	-	-	-	-
Orthoptera ^{vi}	<i>Gryllus bimaculatus</i>	120	-	-	-	-
Orthoptera ^{vi}	<i>Oxya japonica</i>	149	-	-	-	-
Orthoptera ^{vi}	<i>Cyrtacanthacris tataria</i>	89	-	-	-	-
Orthoptera ^{viii}	-	-	3.49	68.75	7.36	74.21
Hymenoptera ^{i, v}	<i>Apis mellifera</i>	-	2.20	21.0	12.30; 31	-
Hymenoptera ⁱⁱ	-	-	-	13–77	-	-
Hymenoptera ^v	<i>Bombyx mori</i>	-	-	-	29	-
Hymenoptera ^{iv, vi}	<i>Oecophylla smaragdina</i>	1272	3.95	62.86	6.81	13.79

Table 5.2 continued

Hymenoptera ^{iv, vi}	<i>Oecophylla smaragdina</i>	1272	3.95	62.86	6.81	13.79
Hymenoptera ^{vi}	<i>Atta mexicana</i>	404	-	-	-	-
Hymenoptera ^{viii}	-	-	-	67.50	-	69.95
Hymenoptera ^v	<i>Anoplolepis</i> spp.	-	3.69	61.37	-	-
Hymenoptera ^{iv}	<i>Tapinoma</i> spp.	-	1.38	52.68	2.65	36.78
Hymenoptera ^{viii}	-	-	6.29	58.62	10.60	57.47
Hemiptera ⁱⁱ	-	-	-	42 – 74	-	-
Hemiptera ^{iv}	<i>Nephotettix</i> spp.	-	2.25	71.18	-	14.77
Hemiptera ^{viii}	-	-	3.04	63.75	16.50	66.30
Lepidoptera ⁱ	Caterpillar	-	1.60	20.00	15.20	111.3
Lepidoptera ⁱ	Caterpillar	-	2.50	23.0	10.20	102.4
Lepidoptera ⁱ	Caterpillar	-	4.10	18.90	18.60	122.2
Lepidoptera ⁱ	Caterpillar	-	3.20	25.7	23.21	100.5
Lepidoptera ⁱ	Caterpillar	-	1.50	20.2	14.20	111.0
Lepidoptera ⁱⁱ	-	-	-	14 – 68	-	-
Lepidoptera ^v	<i>Galleria mellonella</i>	-	-	-	57	-
Lepidoptera ^{vi}	Silkworm	94	-	-	-	-
Lepidoptera ^{viii}	-	-	4.52	64.38	12.00	64.78
Diptera ⁱⁱⁱ	<i>Drosophila melanogaster</i>	-	-	0.130 ± 0.005	0.083 ± 0.008	-
Diptera ^{viii}	-	-	3.20	61.81	9.55	75.26
Odonata ⁱⁱ	-	-	-	46 – 65	-	-
Odonata ^{viii}	-	-	-	68.13	-	70.64
Isoptera ⁱ	<i>Macrotermes bellicosus</i>	-	2.90	20.4	28.2	136
Isoptera ⁱ	<i>Macrotermes notalensis</i>	-	1.90	22.1	22.5	114
Homoptera ⁱⁱ	-	-	-	45 – 57	-	-
Dictyoptera ^{viii}	Blattodea	-	8.43	68.13	10.90	63.61
Araneae ^{viii}	-	-	4.19	76.25	9.55	84.43

Superscripts represent source of references. ⁱBanjo et al., 2006; ⁱⁱXiaoming et al., 2010; ⁱⁱⁱWilder et al., 2010; ^{iv}Tuen et al., 2012; ^vBednarova, 2013; ^{vi}van Huis et al., 2013; ^{vii}Yang et al., 2014; ^{viii}Razeng & Watson, 2015.

5.1.6 Research Questions and Objectives

Diets of insectivorous birds, as shown above, consisted of a wide array of prey groups with Coleoptera the food choices of many from different regions. Tropical forests house enormous species of invertebrate that are potential food for other animals in the food web (Nyffeler et al., 2008). In Chapter 4 of the current study, 17 orders of invertebrate were recorded in the sampling areas, however there was no guarantee that babblers would feed on them all. Additionally, babbler assemblage is confined to the understorey and coexistence also takes place, so the questions raised here were

1. Do the babblers feed on all 17 orders of prey groups in all the sampling stations?
2. If they are selective, why were certain order or species were chosen?
3. What would be the diet breadth for each babbler species?
4. Do babblers choose their prey based on its availability in the habitat? If it does, then the frequency of occurrence in the diet should mirror that in the environment.
5. Do they select prey based on sizes because large size prey potentially offers greater reward, or do they select their prey based on nutritional quality? Are there external or morphological cues that attract predator to select or reject a prey?

The objectives of this chapter were

1. to determine the diet of different species of babbler, based on identifiable parts in regurgitated samples, stomach samples and excrements,

2. to determine if the birds are opportunists (consume insects based on availability) or specialists (eat only certain species)?
3. to determine the relationships between sizes of predators and prey
4. to determine the nutrient contents (ash, gross energy, crude protein and phosphorus) of arthropod prey.

5.2 Materials and Methods

5.2.1 Bird Diet Sampling

Sampling procedures have been described in Chapter 3. After measurements were taken, all captured individuals (except juveniles) were retained to collect diet items by administering 1% emetic solution, which induces vomiting. A solution of 1% of tartar emetic was prepared by diluting 5 g antimony potassium tartrate (APT) in 500 ml of distilled water (Pang et al., 2017). No administration was done to one individual captured twice or more on the same day to avoid mortality resulting from over-dose.

The tartar emetic was administered by orally giving 0.2 cm³ amount of 1 % solution of APT solution via a flexible rubber tube inserted at the tip of the syringe. The tube was inserted through the bill, gently down to the opening of oesophagus, to ensure the amount given is fully administrated. It was done slowly and steadily without harming the birds. Dosed individuals were each then put into a cylinder-shaped container with holes for ventilation, the container with the bird inside was covered with an opaque cloth to minimise stress. Ten minutes later, the birds were released (Pang et al., 2017), irrespective of whether they regurgitated or not. Regurgitation was only conducted on birds captured between 1000–1800 hours, to give time to the birds to forage in the early morning or to

forage late in the afternoon and have food in their stomachs for the night. Any bird which showed signs of weakness after regurgitation were given appropriate amount of commercial glucose solution for recovery prior to release.

In the event of the faecal samples being produced during retention, they were also collected separately from regurgitated sample. Birds that died during capture were dissected in order to extract the stomach for content analysis. Regurgitated, faecal samples and the stomach contents were then preserved in 70 % ethanol separately.

5.2.2 Examination Regurgitated, Stomach and Faecal Sample in Laboratory

All three types of samples, regurgitated, faecal and stomach content were brought back to laboratory for further investigation. Sorting and identifying the dietary fragments were carried out on a petri dish under a binocular stereoscopic microscope (Motic, BA410 series, China) at magnifications of 10x. Prey items were examined for both intact body or fragmented body parts and identified to the lowest level of classification possible mostly at the ordinal level. Challenges included identification from body parts, such as head and elytra, which are resistant to digestion as they are a sclerotized part of the body (Hódar, 1997).

As most of the prey items found in the sample are greatly fragmented, the count of the prey on individual basis was challenging and produce unreliable result (Moorman et al., 2007). Instead, prey items were counted based on their occurrence in the number of birds that consumed them.

5.2.3 Data Analysis

5.2.3.1 Babbler Prey Preferences and Selection

Overlapping of babbler diets was analysed in R package *Birpartite* (Dormann et al.; 2008), to look into the relationship between predators (the babblers) and their prey.

In order to determine prey selectivity, the formula below was used, where r is prey found in the sample, p is prey found in the field, D_{fr} is the level of preference (Jacobs, 1974) with value ranging from -1 to 1, where -1 indicates the prey was avoided by the bird and 1 indicating prey was preferred by the bird (Mallet-Rodrigues, 2001).

$$D_{fr} = (r - p) / (r + p - 2rp) \dots\dots\dots \text{Jacob's index, (1974)}$$

5.2.3.2 Relationship Between Body Size of Selected Prey and of Babbler

The associations of body sizes of selected prey and babblers were tested by using regression function in R (R core team, 2018). The variables used are lengths of selected body parts of prey against weights of babblers.

5.2.3.3 Accumulation Curve of Captured Prey

Accumulation curves of consumed arthropod prey were obtained by using package *vegan* (Oksanen et al., 2007) in R (R Core Team, 2018). Method chosen is exact (y-axis) which implies that the exact individual numbers of each species were used for the analysis, over total number of prey groups (x-axis).

5.2.4 Prey Sample Chosen for Analysis

Arthropod prey chosen for nutritional analysis were those collected from pitfall traps and leaf litter, being intact individuals. The number caught were far lower than in sticky traps, so only arthropods that are plentiful, for example ants and termites were used. The sticky traps had strong adhesive surface and although large number of arthropods were entrapped, they were difficult to remove. Their body parts were usually torn apart if forcibly removed from the sticky trap. Thus, arthropods captured on sticky traps were identified but not analysed.

The other criteria for choosing samples for nutritional analysis were based on knowledge from previous studies (e.g., Anthal & Sahi, 2013; Zaman, 2012) that they were consumed by babblers. The samples chosen for analysis were dried and stored in the oven with temperature was set constantly at 60°C; and the results were reported on dry matter basis in all analyses.

5.2.5 Laboratory Analyses

Nutritional analysis was performed to determinate of (i) ash (ii) inorganic phosphorus, (iii) crude protein and (iv) gross energy.

5.2.5.1 Ash Determination

The method applied by Sluiter et al. (2008) was adopted in this study, with slight modifications. Instead of 1 g of ground sample, each replicate was an individual of an arthropod order. Analysis was done in triplicate whenever the amount of sample permitted. Empty crucibles were weighed accurately using analytical balance (W_1). An individual of dry arthropod was put into the crucible and weighed together (W_2). The crucibles containing sample were put inside the 1,200°C-Laboratory Chamber Furnace (Elite

Thermal Systems Limited, model BSF12/22) and incinerated at 500°C for 5 hours. Crucible with ash were taken out and put in the desiccator to cool down and then weighed (W_3).

Calculations:

Weight of dry sample, W_4 (g) = $W_2 - W_1$

Weight of ash, W_5 (g) = $W_3 - W_1$

Ash (as % of DM) = $(W_5 / W_4) \times 100$

5.2.5.2 Phosphorus Determination

The ashes (from ash determination above) were dissolved with 25 ml of 2 M Hydrochloric Acid (HCl). The solutions were filtered into a volumetric flask (50 ml) as a working unit. Crucibles were rinsed many times with distilled water and the washings were filtered into the flask. The solutions were made up to 50 ml with distilled water (Van Keulen and Young, 1977). It was mixed well and stored for phosphorus determination.

Phosphorus (P) concentration in the ash solution was determined using a UV-spectrophotometer (Optima, SP-3000 – Plus model) following the metavanadate method (Szydłowska-Czerniak & Szlyk, 2003). The wavelength was set to 420 nm and slit width set to 1.0 nm.

The standard range containing 1, 2, 3 and 4 ppm P was prepared by mixing distilled water, 0.1 M hydrochloric acid (HCl), reagent A (ammonium molybdate) and B (ammonium metavanadate) and phosphorus standard solution (10 ppm) according to Table 5.3.

Table 5.3: Preparation of standard range containing 1, 2, 3 and 4 ppm phosphorus.

P Concentration ($\mu\text{g/ml}$)	0	1	2	3	4
P working standard, ml	0	1	2	3	4
Distilled water, ml	4	3	2	1	0
0.1 M HCl, ml	2	2	2	2	2
Reagent A+B, ml	4	4	4	4	4
Total volume	10	10	10	10	10

The sample was prepared for analysis as follows: 3 ml sample solution, 1 ml distilled water, 3 ml HCl and 2 ml of Reagent A + B were pipetted into a test tube in sequence. After allowing for 30 minutes of reaction time, the absorbance of the standard and sample solution was determined and P concentration in the sample tube was calculated automatically by the spectrophotometer. The concentration of P in the sample was calculated by multiplying the concentration of P in the sample tube by the dilution factor and divided by the weight of the sample.

5.2.5.3 Crude Protein Determination

Total nitrogen (N) content was determined using the Kjeldahl method (Simonne et al., 2002). Weighed dry sample was put into digestion tubes, into which was added one selenium catalyst tablet and 10 ml of concentrated Sulphuric Acid (H_2SO_4). Digestion was carried out for approximately 45 minutes on a Büchi, Kjeldigester (model K-446), until the solution was clear. Distilled water (50 ml) and 20-25 ml 30% NaOH was then added to the clear solution to make it alkaline and then distilled on a Büchi, Distillation Unit (model K-355 model). Ammonia gas released during distillation was trapped in 4% aqueous solution of boric acid containing methyl red-bromocresol green indicator. Total N was determined by titrating the trapped ammonia gas using a standard acid (0.1 M HCl), until a faint pink colour was obtained. Crude protein content was calculated by multiplying % N by 6.25 (Williams, 1984).

Calculations:

$$\% \text{ N} = (\text{titre volume} \times 0.1 \times 1.4007) / W_6$$

$$\text{Crude protein (\%)} = \% \text{ N} \times 6.25$$

Whereby, 0.1 is the concentration of the standard acid (0.1 M HCl), 1.4007 is the atomic weight of N and W₆ is the weight of the sample.

5.2.5.4 Gross Energy Values Determination

Gross calorimeter values of arthropods were determined using a bomb calorimeter (IKA® Calorimeter System, model C 2000), according to the method of Pascual & Ciancio (2006). Prey such as beetle, bee, and fly with relatively larger bodies were analysed individually, while those with comparatively smaller bodies, such as ants and mayflies were analysed by a group of three or four individuals. Prey were put in a manufactured plastic, separately as a combustion aid. All dried samples were weighed and using analytical balance. A cotton thread (with a known energy value of 50 J) was fastened over the ignition wire and put in the crucible. Weighed sample was placed on the thread in the crucible. All above mentioned parts were put into the combustion vessel and closed with a cap screw. The combustion vessel was connected to the oxygen filling device and automatically ignited once the required oxygen pressure was reached. The result of the analysis, together with the experiment parameters, was shown on the display panel and stored in a memory card.

5.3 Result

5.3.1 Composition of Babbler Diets

A total of 307 babblers were netted during the study. Of that, 43 babblers were captured at either 0800 hour or after 1800 hour. These were not dosed because the ones captured at the former time period has not had a chance to feed while those captured after the latter time needed energy to last them through the night. Forcibly regurgitated individuals might not be able to catch insects in the dark 1800 hour.

Seventy-eight babblers were administered with APT but yielded no sample of any type. A total 110 regurgitated samples (from 105 individuals), 58 faecal samples and 27 stomach content were collected for further analysis.

Eleven intact prey individuals were found from regurgitated samples and one each from faecal and stomach content. Five prey types were hymenopterans, two dipterans, an ephemeropteran, a caterpillar and seven individuals of the same species belonging to Gastropoda (Table 5.4). Other arthropods were identified by their body fragments, for example, the elytra of Coleoptera, head of ants and the eyes of spiders.

Table 5.4: List of babbler species and ordinal categories of prey recovered from regurgitated (R) and faecal (F) samples and stomach content (S). The prey were identified from intact individuals (I) or body parts (P).

	Babbler species	Arthropods	Figure no.
1	Grey-headed Babbler	Ephemeroptera (I, R)	A
2	Grey-headed Babbler	Hymenoptera (I, R)	B
3	Fluffy-backed Tit Babbler	Hymenoptera (I, R)	C
4	Fluffy-backed Tit Babbler	Caterpillar (I, R)	D
5	Chestnut-winged Babbler	Diptera (I, R)	E
6	White-chested Babbler	Diptera (I, R)	F
7	Chestnut-winged Babbler	Hymenoptera (I, R)	G
8	Fluffy-backed Tit Babbler	Gastropoda (I, R)	H
9	Short-tailed Babbler	Hymenoptera (I, F)	I
10	White-chested Babbler	Coleoptera (P, F)	J
11	Black-throated Babbler	Hymenoptera (I and P, S)	K
12	Grey-headed Babbler	Araneinae (P, F)	L

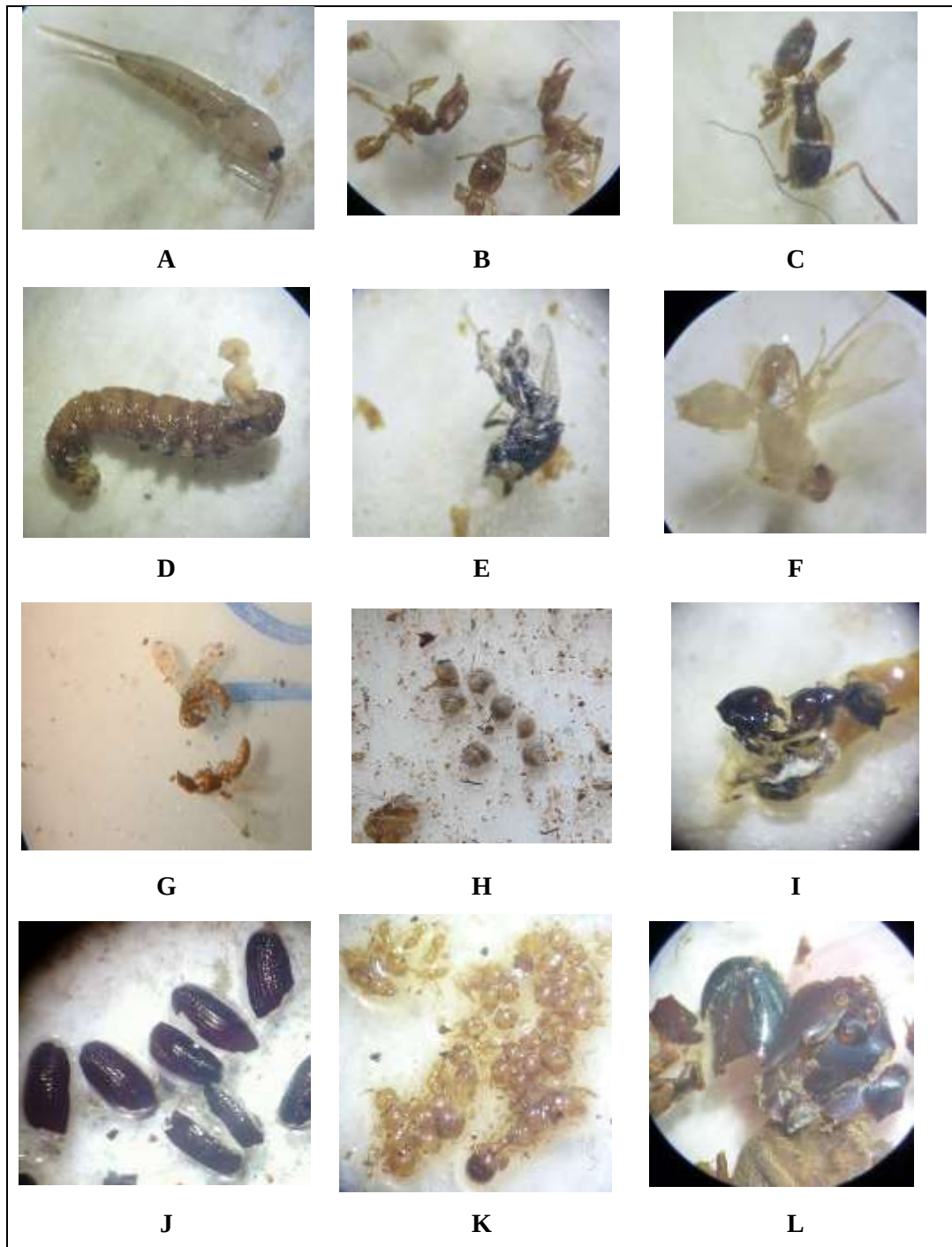


Figure 5.1: Prey consumed by babblers at Pelagus, Kapit.

Composition of prey items recovered from regurgitated, faecal sample and stomach content comprised 10 arthropods and a gastropod (Figure 5.2). The major constituents were Coleoptera, which accounts for 40% of the total, followed by Hymenoptera (16%), Arachnida (12%) and Orthoptera (12%). The minor constituents are caterpillar (6%), Hemiptera (4%), Diptera (3%), Gastropoda (1%), Ephemeroptera (1%), Dictyoptera (1%) and Isoptera (1%).

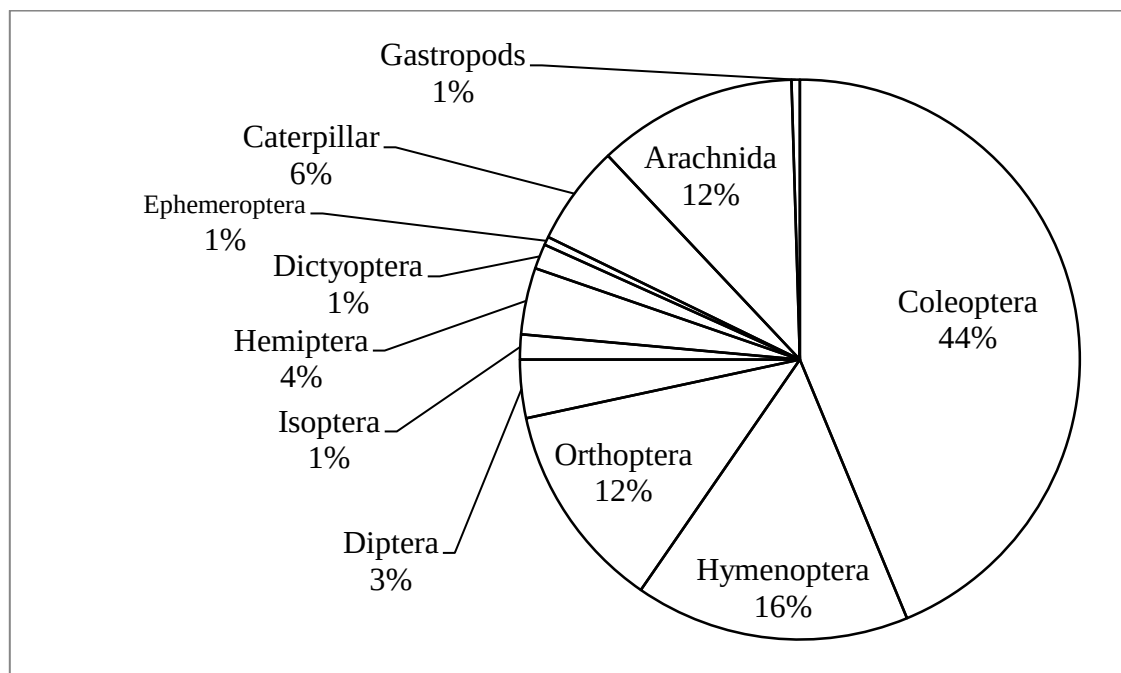


Figure 5.2: Ordinal prey group constitutions collected from babblers at Pelagus, Kapit.

Figure 5.3 shows the accumulation curve of arthropod prey taken by babblers in this study. As the curve is still increasing and not reaching its asymptote, it indicates that the prey groups consumed by the babblers captured in this study have not been fully discovered.

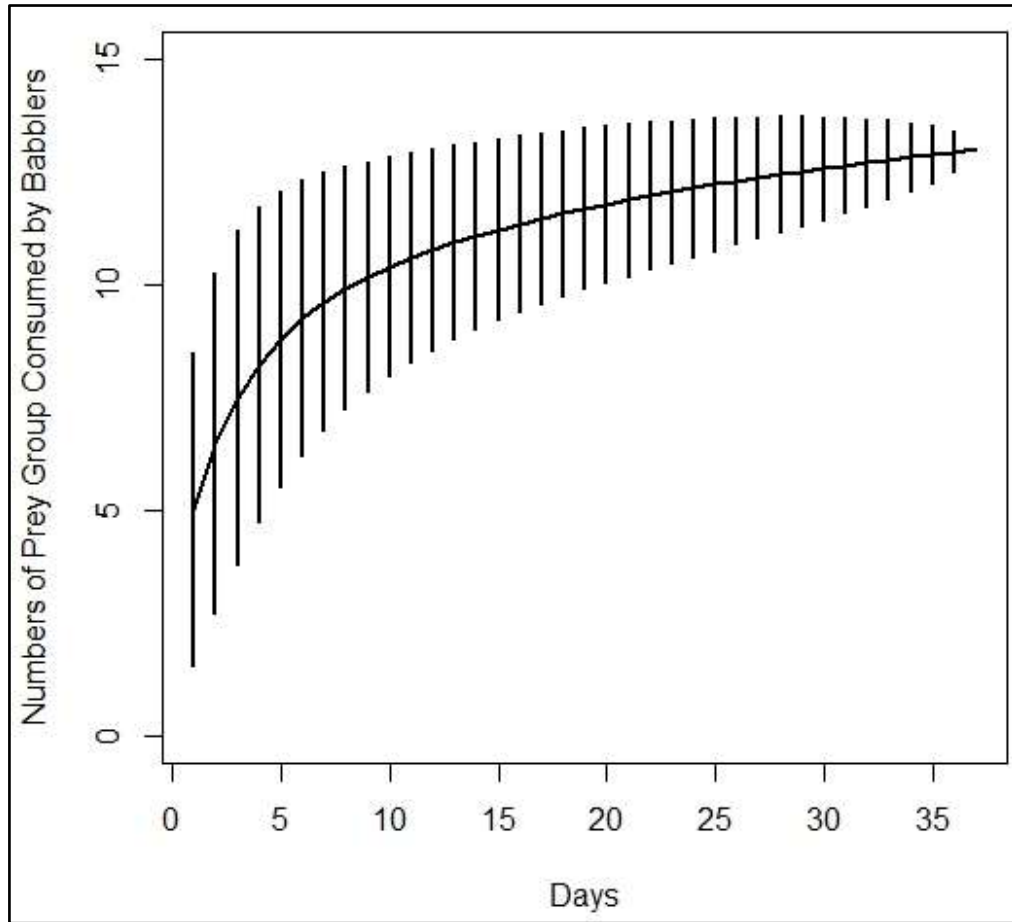


Figure 5.3: Accumulation curve of ordinal prey items found from babblers caught in Pelagus, Kapit.

5.3.2 Babbler Diet Breadth and Selection

The diet breadth of 16 babblers captured in this study is shown in Figure 5.4. The upper blocks are the list of prey item. The wider they are, the more of them were found in the sample. The lower blocks are the babbler species which provided the samples. The width of each block represents accumulative number of individuals. The lines that connect the upper and lower blocks indicates how frequent prey items were encountered in babblers, with the broader line showing that more of the prey was consumed.

This figure also shows how diet overlaps among species. Diet overlap in the context of this study is defined as the same prey groups consumed by two or more species. Multiple lines in one block means there are more overlap of prey groups.

Coleoptera was the most selected among the prey items, being consumed by 15 babbler species, except BSTB. Hymenoptera were found consumed by 12 babbler species, while Araneida and Orthoptera were eaten by 10 species. Caterpillar was eaten by five babbler species, Hemiptera by five, Diptera by four, Dictyoptera by three, Isoptera by two and, Ephemenoptera and Gastropoda by one.

STB was recorded to consume most prey – 10 groups. The broad line shows that many species had Coleoptera in their diets. The second and third broader lines indicate that the Hymenoptera and Araneida were the second and third most consumed prey for this babbler species, which also fed on Hemiptera, Caterpillar, Isoptera, Dictyoptera and Diptera.

Another consumer of Coleoptera was CWB. In addition to that, Orthoptera, Araneida, Hymenoptera and Diptera were eaten too. Six types of prey were found in the diet of FBTB. They are Orthoptera, Coleoptera, Hymenoptera, Araneida and caterpillar. Gastropoda was found in the sample collected from only FBTB. Three species of babbler (GHB, BTB and SCaB) were found with a relatively narrower diet breath. The prey consumed by GHB consisted of Coleoptera, followed by Araneida, Orthoptera, Hymenoptera and Hemiptera. Only GHB was found consuming Ephemenoptera. Alongside Coleoptera and Hymenoptera, BTB also fed on Isoptera, Araneida and caterpillar. Five orders were known eaten by SCaB. They are Coleoptera, Hymenoptera, Orthoptera, Dictyoptera and Araneida.

Five other babblers, - RCB, FB, MB, BCB, and CRB consumed a variety of prey, ranged from three to five types, but CBSB was only found feeding on two orders, and SCB, BSTB and HB, one each due to limited sample obtained.

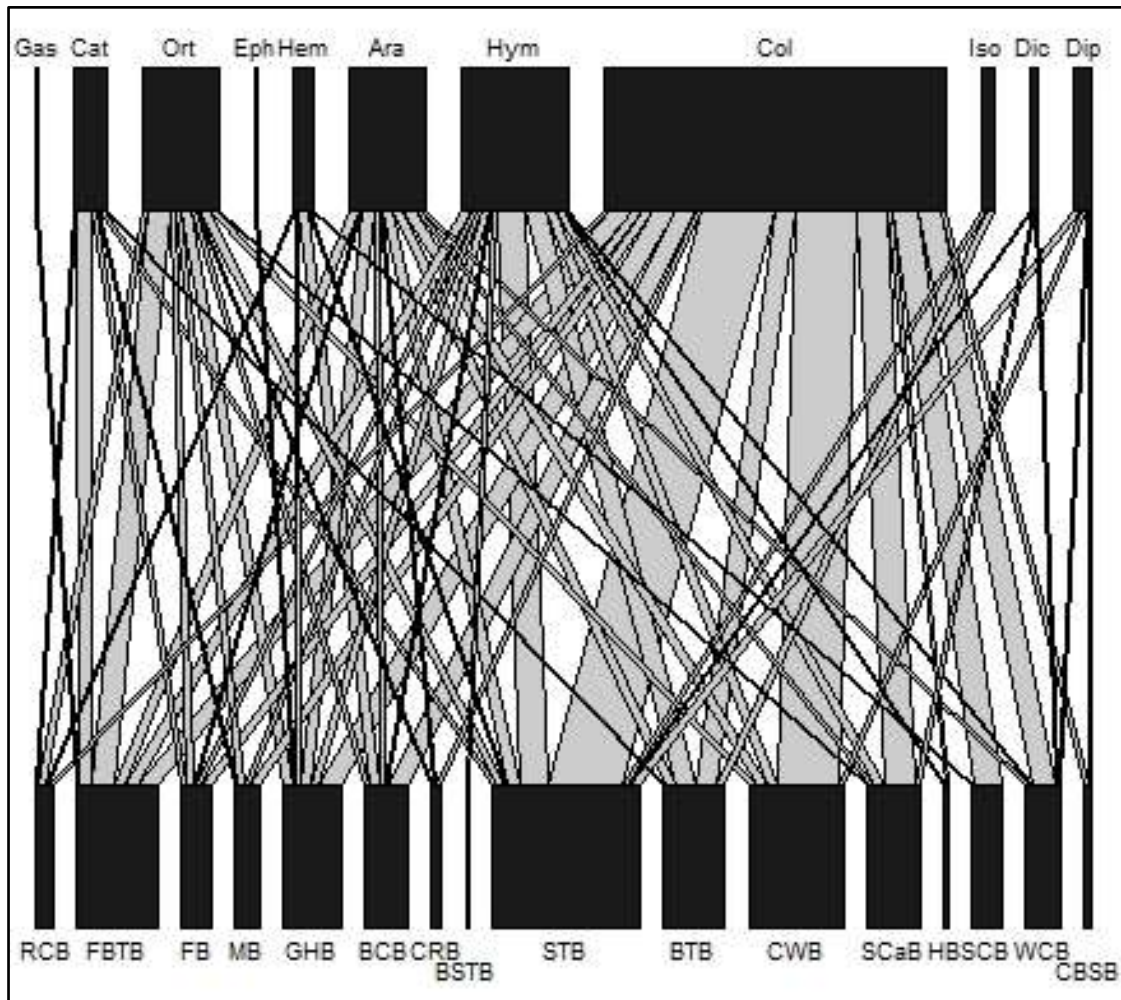


Figure 5.4: Diet breadth of babblers captured in Pelagus, Kapit throughout the study period.

5.3.3 Prey Preference

Preference index for different prey is given in Table 5.5. Positive values of D_{fr} indicate preference while negative values indicate avoidance. Caterpillars were the most preferred prey by the babblers in this study, with D_{fr} value of 0.98. This was followed by Orthoptera, Araneida, Coleoptera and Hemiptera with value of 0.92, 0.84, 0.82 and 0.78.

Less preferred preys were Dictyoptera and Isoptera, with D_{fr} value only 0.23 and 0.22. Coming in first and second with the highest capture number from the traps but with low encounter in babbler diet samples, Diptera and Hymenoptera thus were not preferred alongside the Ephemeroptera, Dermaptera, Lepidoptera, Odonata, Phasmida and Siphonaptera.

Table 5.5: Level of preferences (Jacob's Index) of types (ordinal categories) found in babblers captured in Pelagus, Kapit.

	Estimated number of prey of babbler	r	Total encounter number of prey in trap samples	p	D_{fr} (Level of preferences)
Lepidoptera (Cat)	12	0.057	15	0.000	0.976
Orthoptera	25	0.118	105	0.005	0.924
Araneida	24	0.113	221	0.011	0.840
Coleoptera	95	0.448	1519	0.076	0.817
Hemiptera	8	0.038	96	0.005	0.782
Dictyoptera	3	0.014	177	0.009	0.234
Isoptera	3	0.014	184	0.009	0.216
Hymenoptera	33	0.156	6013	0.299	-0.397
Ephemeroptera	1	0.005	335	0.017	-0.563
Diptera	7	0.033	11295	0.563	-0.948
Dermaptera	0	0	17	0.000	-1
Lepidoptera (adult)	0	0	96	0.005	-1
Odonata	0	0	1	5E-05	-1
Phasmida	0	0	1	5E-05	-1
Siphonaptera	0	0	2	1E-04	-1

5.3.4 Relationships Between Weight of Babbler and Size of Prey

To investigate whether there is any relationship between size of babbler and size of their prey, babbler body weights (proxy for size) were plotted against the length of their prey body parts (Figure 5.5). The plots showed that relationship between babbler weights and length of prey body fragments is not significant, as indicated by horizontal regression lines, respectively. The length of Coleoptera elytra and the head length of Hymenoptera are

negatively correlated to weight of babblers, ($r^2 = -0.004092$, $p > 0.05$) in A, $r^2 = -0.02178$, $p > 0.05$ in C). The relationship between the length of Orthoptera forum (hind legs) is positive correlated ($r^2 = 0.7448$, $p > 0.05$ in B).

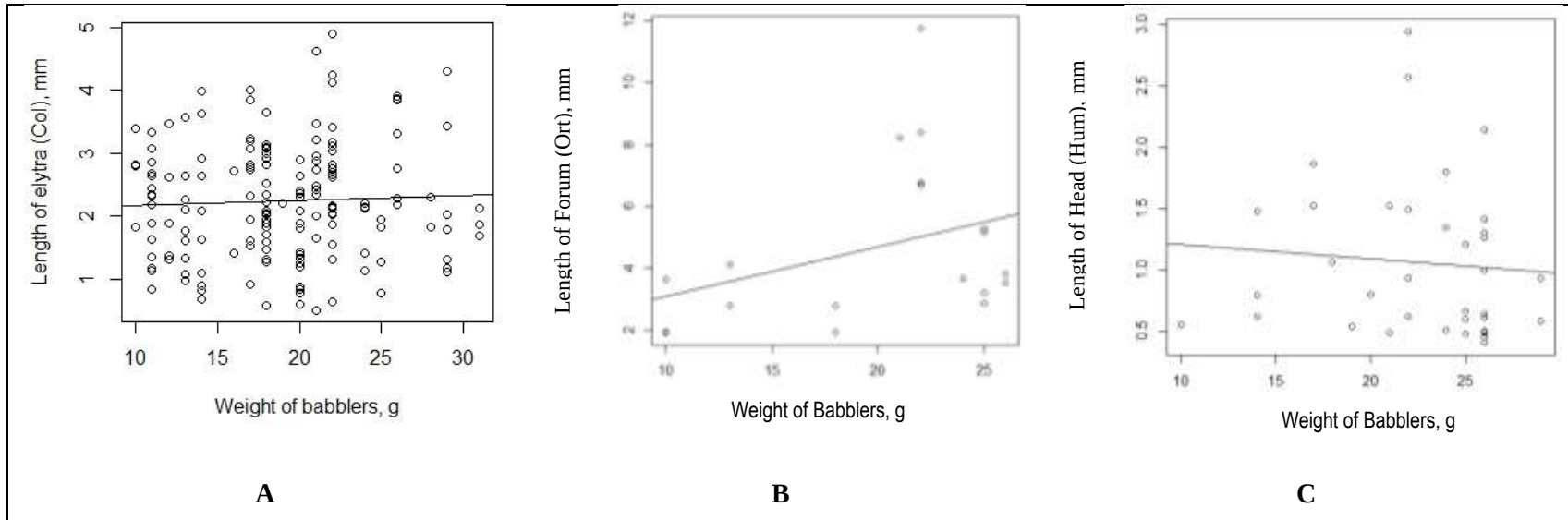


Figure 5.5: Relationships between weights of babblers (g) and the length of selected prey body parts (mm). Babbler vs elytra (wing cover of Coleoptera), r^2 value is -0.004092 (A). Babbler vs forum (hind legs of Orthoptera), r^2 value is 0.7448 (B). Babbler vs heads (Hymenoptera), r^2 value is -0.02178 (C).

5.3.5 Nutrient Contents of Potential Prey

The focus of the analysis is on crude protein and energy, since these two are the most important nutrients required by the body. Due to limited sample used for analysis, only Diptera, the Formicidae of Hymenoptera and caterpillar had enough sample for ash analysis. Ephemenoptera showed low crude protein content compared to the others, while Diptera and caterpillar has three times higher phosphorus than all other analysed samples. Orthoptera had the highest crude protein value (87.1%) and red ant had the highest energy value (23.9 KJ/g).

Table 5.6: Ash, crude protein, gross energy and phosphorous content of prey item (ordinal categories). NA indicates analysis not done due to insufficient sample.

Order	Ash %	Crude Protein %	Energy (KJ/g)	Phosphorus (mg/g)
Odonata	NA	NA	13.322	NA
Ephemenoptera	NA	25.16	13.180	NA
Orthoptera	NA	65.53 - 87.1	18.074	NA
Hemiptera	NA	60.74	18.349	NA
Coleoptera	NA	53.77	17.905	NA
Diptera	15.81	69.83	13.019	20.98
Hymenoptera				
Super family:				
Apocrita				
Non-formicidae	NA	71.68	16.960	5.93
Formicidae				
1. <i>Oecophylla maragdina</i> (red ant)	3.58	74.56	23.938	2.32
2. <i>Polyrachis</i> sp. (black ant)	2.60	65.57	12.437	NA
3. <i>Camponotus gigas</i> (giant ant)	7.49	73.9	17.288	7.49
Araneida	NA	83.24	18.890	NA
Caterpillar	11.44	47.9	19.975	32.44

5.4 Discussion

This study showed there are higher chances in getting intact individual prey from regurgitated sample compared to stomach contents and faecal samples. This was similar to the findings of Carlisle and Holberton (2006).

The removal of stomach, itself was done if there was a dead specimen. As shows in Table 5.1, mortality increased if the concentration of the emetic solution was not carefully considered. It could be also due to the species, and surrounding conditions. For example, according to Carlisle and Holberton (2006), 17 of a group of 18 *Junco hyemelis* (Dark-eyed Juncos) in captivity were given the solution, died after 30 minutes of the administration. Also subjected to the similar techniques, two out of 130 wild migratory birds like *Vireo gilvus* (Warbling Vireo) died of emetic solution. This implies that the administration of the solution may be fatal on captive birds. Nevertheless, Poulin et al. (1994) demonstrated that tartar emetic was a safe method, as it was successfully applied to all species ranging from nectarivores to frugivores, and the success rate in getting the regurgitated samples was also high (88 %).

Although the analysis of faeces is preferable to some researchers in predicting the diets of birds (Ralph et al., 1985; Baker-Gabb, 1988; Parrish et al., 1994; Burger et al., 1999; Moorman et al., 2007; Orłowski & Karg, 2013), which some showed relatively good results, the collection of faeces sample was too little. In additional, the majority of the body parts on faecal sample in this study were heavily fragmented, which make the prey identification challenging, as Moorman et al. (2007) experienced.

Babblers were reported to employ a wide variety of foraging tactics as their prey varied in mobility and distribution level in understorey. For example, a WCB was observed

perching on the twig and stretching its head to feed on the colony of ants walking on another twig and CWB was seen applying similar foraging strategy, stretching in dead leaves (Mansor et al., 2015, Styring et al., 2016).

Coleoptera was an important component of babbler's diet, as reported in many other studies in the past (Sodhi et al., 2010; Siqueira et al., 2015; Sainz-Borgo, 2016; Sayer et al., 2016). This may be due to Coleoptera being the most cosmopolitan and abundant family in class insect (Hill & Abang, 2010) and being the most dominant arthropod in the understorey (Gaiotti & Pinho, 2013). Additionally, chances in getting Coleoptera from the identification were higher than others as its body parts, especially the outer wings (elytra) being hard to digest. In addition, coleopterans are generally slow movers, which make them easy targets for predators (Pang et al., 2018). Despite the high collection from the traps, Coleoptera is not the most preferred prey of all.

Hymenoptera, Orthoptera, Araneida, caterpillar and Hemiptera also contributed to the diet of babblers. Jacob's indices showed that the caterpillar, Orthoptera and Araneida ranked at the top three in the preference list. This could be because they provide rich nutrients. Caterpillars analysed in this study had second highest gross energy value and highest concentration of phosphorus. Banjo et al. (2006) also found caterpillars to be relatively phosphorus-rich arthropods. Orthoptera, was found to contain high protein in this study, while Xiaoming et al. (2010) reported this order not was only protein-rich but also high in phosphorus. Orthoptera contained the highest amount of protein, Araneida was high in protein and gross energy, similar to the finding of Razeng and Watson (2015). This may also explain why these three were preferred by *P. major* for their nestlings (Mizutani & Hijii, 2002; Mallord et al., 2016).

Hymenoptera seems to be avoided by babblers in this study, although past researches demonstrate that Hymenopterans were frequently consumed by birds (Gaiotti & Pinho, 2013; Sainz-Borgo, 2016). The encounter frequency of Hymenoptera in the diet sample was low despite it being the second-most collected prey after Diptera. Despite ants being always numerically abundant, babblers did not consume them in accordance to their abundance, except BTB. One WCB that was given emetic solution and released was seen to perched on a tree with ants, it was sighted eating only a single ant before it flew off (pers. obsv.).

Alongside other prey that are avoided by babblers, such as Dermaptera, Lepidoptera, Odonata, Phasmida and Siphonaptera, the Jacob's index shows that Diptera was also not preferred by babblers albeit found in babbler diets. Comparatively, it has high protein content. Numerous Diptera egg were seen during the process of grinding. This may contribute to the phosphorus content. Razeng and Watson (2015) also demonstrated that the pool sample of Diptera analysed were protein-rich but *Drosophila melanogaster* was low in both crude protein and fat (Wilder et al., 2010).

Unlike previous researches, no values on crude fat were reported. This is due to insufficient sample collected from pitfall and leaf litter extraction. Sample captured by sticky traps, though numerous, they were too adhered to the glue and difficult to extract without breaking them apart.

Although body size was reported playing important role in the coexistence of sympatric species in the community, and which large birds were hypothesised consuming large prey in this study, the results show that there is no correlation of sizes between prey body parts and predators.

Sizes of prey are reported to be positively correlated to the that of predators (Mohd-Azlan et al., 2014). Previous study compared the sizes of birds with that of prey in pooled sample and thus produced a positive correlation. The findings in this study have both negative and positive correlation. That suggests that babblers are generally opportunistic feeder. When different preys are available, they choose prey on sizes such as the Orthoptera. Babblers also feed on prey that are available regardless of their sizes. Small prey, such as ants were consumed by BTB (a relative larger babbler) would take many of them to fulfil their daily requirement.

Mizutani and Hijii (2002) showed that *P. major* consumed larger prey than did *P. varius* although in terms of sizes they were similar. Prey of *P. varius*, though small, showed wider ranges. On the contrary, Leyequi  n et al. (2006) reported that body masses did not influence the competition strength significantly, but high variation of body masses in a community would promote better coexistence.

5.5 Conclusion

The following conclusions can be made from this study:

- i) Babbler prey groups consisted of ten arthropods (Coleoptera, Hymenoptera, Arachnida, Orthoptera, Lepidoptera, Hemiptera, Diptera, Ephemenoptera, Dictyoptera and Isoptera) and one gastropod. Intact individuals recovered from the diet samples include five hymenopterans, two dipterans, one ephemenopteran, one caterpillar and seven snails.
- ii) Jacob's index reveals that caterpillar was the most preferred prey despite coleopterans constituting the greatest part of the diets of babblers in this study.

- iii) Babblers may be opportunist feeders, feeding on coleopteran as these are the most abundant prey in the forest. Prey selection among babblers are varied but selection does not seem to be based on prey size. Gastropods were consumed only by FBTB while GHB had ephemenopteran in their diets.
- iv) Nutritional analysis done on nine orders of arthropods revealed that red ant (Hymenoptera) has the highest gross energy content (571.75 kcal/100g); fly (Diptera) has the highest ash content, (15.81%); grasshopper (Orthoptera) and caterpillar (Lepidoptera) are protein and phosphorus-rich arthropods, respectively.
- v) It seemed that babblers have developed interspecies resource partitioning to avoid competition and gaining nutrients from different types of prey.

CHAPTER 6

GENERAL DISCUSSION

Despite babblers recorded in the current study, are under the same clade and family, and sharing similarities among them, yet they are different in many ways. The results in Table 3.6 showed that coexistence of babblers occurred at all stations, accounting from seven to 13 species. Stations with the least diversity, PL500 and B100 with respective disturbances indices of 14.38 and 19.26, shared five babbler species. FB and HB were found in PL500 but not in B100, STB and WCB are vice versa. The non-capture of these species is unlikely to indicate their non-adaptation to disturbance because they were also found in other stations. In fact, STB were trapped in all stations but PL500. Their absence in the list of that station could be merely that they were not captured.

Stations with the most species were PL1000 and PR1000. Both stations are located 1,000 m from human settlements, but the former was less disturbed compared to latter where logging skid trail were still being used. Nevertheless, Shannon indices showed that the diversity of babbler were 2.316 and 2.132. These results suggest that, though disturbed, the areas support small-bodied understorey birds (Edwards, et al., 201; Hamer et al., 2015). It could also be that most babblers, for instance STB, BTB, FBTB, and CWB in Pelagus, are habitat-generalist and adaptive to different levels of disturbances, although many regard babblers as primary forest birds which are sensitive to the environmental changes, being understorey residents (Zakaria, 2000). Different multispecies interaction could also be taking place, as reported in the Amazon (Siqueira et al., 2015), thus contributing to the diversity of babbler at the 10 stations in this study.

The logging companies agreed to the villager's proposal to protect water sources by restricting the cutting trees in areas further than 1,000 m from settlements. This made the stations located at 1,000 m away from the settlements closer to the logged areas. In fact, one of the stations, PR 1000 was within a logged area. Results in Table 3.6 shows that the most distant stations from human settlement had higher number of babbler species than those adjacent to them. Despite the fact they were far from human settlements, these areas were also closer to the post-logged areas. Due to regeneration in human absence and abandonment, previously logged areas were able to regain their diversity (Brodie et al., 2015).

Methods used to capture prey in the current study are also be suitable in studying babbler diet. Similar observations were reported by Johnson (2000), that branch-clipping was the most efficient in collecting arthropods, which consumed by three foliage-gleaning warbler species in Jamaica. A right method not only captures targeted prey, but also could prevent over-capture of arthropod that are not the targeted subjects.

Figure 6.1 shows that prey and babblers in this study are negatively correlated with the canopy cover, similar to finding by Posa and Sodhi (2006) who demonstrate that birds responded positively to canopy opening. The result in Chapter 4 found that canopy cover was the most parsimonious model in predicting the presence of arthropods in the forest. Dense canopy provides them places of concealment. Larger canopy gap allows light and heat to penetrate the forest understorey, thus adding dynamism to prey movement and the opportunities of capturing them become easier. This mechanism could also apply to the babblers as canopy cover also appeared to be most parsimonious model to the occupancy and netting probability of some species, such as CBSB, BTB, GHB, FB and HB. This

result suggests that the dynamic of babblers could be due to the abundance of arthropods at each station. The undergrowth regrew after disturbance and provided food and shelter for insects. This may lure understorey insectivores, such as babblers to forage in regenerating forests.

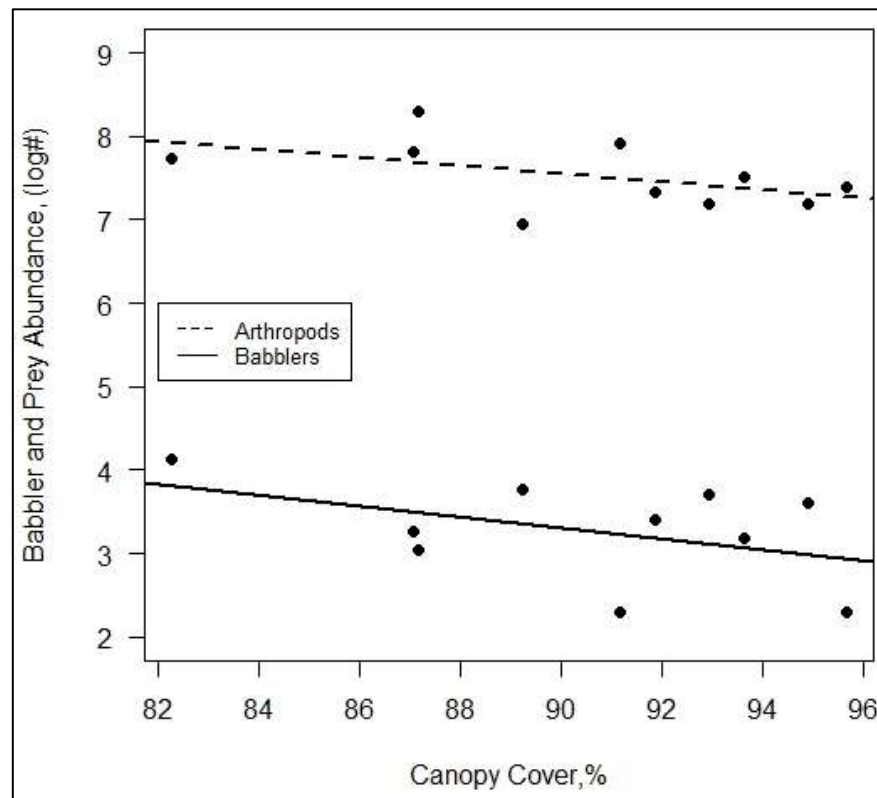


Figure 6.1: Linear regression of prey and babblers (in log number) against canopy covers (%).

In addition to canopy, shallow leaf-litter depth, was a good model for occupancy and detection probability of some babblers' such as CWB, SCaB, MB and WCB. This may reflect their foraging pattern on litter arthropods that closely associate with microhabitats, such as soil (Donoso et al., 2013). During the survey, CWB was seen foraging on the forest floor among the leaf litter. WCB was sighted perching on the twig, 0.5 m above ground

and presumably searching for moving ants. *Turdoides striatus sindianus* (Jungle Babbler) was seen foraging underneath dead leaves (Anthal & Sahi, 2013).

There was compelling evidence of prey overlap among babblers in this study, as reported previously (Wong, 1986; Siqueira et al., 2015; Sherry et al., 2016; Ceresa et al., 2016). Prey that were consumed by most babblers were coleopterans, followed by hymenopterans, arachnids and orthopterans. Despite being the preferred prey, caterpillars were not found in the diets of all species. Perhaps due to their soft bodies, devoid of any indigestible exoskeleton, they were digested rapidly in the alimentary system of the babbler, leaving little evidence of their consumption in many species (Rosenberg and Cooper, 1990). Caterpillar possessing no chitin except the mandibles and that led to underestimation of their importance in the diet or caterpillars were fed to the nestlings, as reported in Mizutani and Hijii (2002) and Mallord et al. (2016). No nestlings were sampled in this study. Hemipterans, Isopterans, Dictyopterans and Dipterans were not shared by many babbler species in this study as they are not favoured, and some were even avoided.

Vertical stratification of babblers in Chapter 3 showed that sympatric babblers would partition their space in the confined areas at the understorey. CWB and STB were caught mainly at Shelf 1 and 2 indicating their space utilisation understorey was on the forest floor or less than 1.2 meter above ground. Mansor et al. (2015) also reported that CWB preferred foraging within the space from 0 to 2 m in the understorey. Chapter 5 shows that the primary prey items of these two babblers were Coleopterans while Hymenopterans were secondary prey items.

Sympatric babblers in this study also partitioned their food resources to avoid competition, similar to the sympatric warblers in the study of Ceresa et al. (2016). In

Ceresa et al. (2016) Reed Warblers consumed Orthoptera in addition to Araneida, Coleoptera, Diptera, Hemiptera and Hymenoptera but Moustached Warblers did not. In the current study, only FBTB was found consuming Gastropods and only GHB eats Ephemeroptera, thus they reduce competition.

The results in this study reveal no association of the total prey found from the diet samples of babbler to the number of prey collected in the sampling stations. Both abundance and species of babbler has no correlation to the disturbance index either. This suggests that anthropogenic disturbance that resulted in a mosaic landscape in Pelagus has little effect on babblers or their diet (Table 6.1).

Table 6.1: Distribution of prey collected from diet sample in relation to babbler diversity from different stations.

Station	Disturbance index	Total number of babbler species	Total individuals babbler	Total potential prey collected	Total prey found from diet
PNP	12.45	10	43	1044	49
PL100	21.87	12	37	1315	41
PL500	14.38	7	20	1640	36
PL1000	11.94	13	41	1315	21
B100	19.26	7	20	2736	12
B500	15.42	8	21	1526	12
B1000	14.44	9	24	1821	7
PR100	16.52	10	26	2464	23
PR500	14.24	10	21	3981	18
PR1000	16.3	13	62	2294	39

Human-induced disturbance is said to alter habitat quality through food resources removal or reduction. The results from the current study show that the prey groups respond only to the canopy cover. A disturbed area with dense closed canopy may still harbour the original population of prey, thus babblers may continue to persist.

CHAPTER 7

CONCLUSION, LIMITATIONS AND RECOMMENDATIONS

7.1 Conclusion

This study suggests the existence of human induced disturbance gradients at Pelagus with areas which were closest to human settlement being the most disturbed. As a result of human activities, the area closest to the longhouse is vegetated by agroforest while secondary forest and logged-over forest occupied the area further behind. The current study further showed that anthropogenic activities that affect the babbler community indirectly through their habitat characteristics, such as canopy cover and leaf litter, are more important than human presence that affect them directly.

An assemblage of babblers comprising 16 species coexist in an avifaunal community comprising 106 species in Pelagus forest. Each babbler species responded to different aspect of the disturbance thus no two stations have same babbler species occurring. Seventeen babblers' potential prey groups captured in the Pelagus forest. All prey are highly responsive only to the canopy covers than other disturbance covariates.

Babblers partitioned their resources in order to enable them to coexist and thrive in degraded forests. Some babblers (for example, CWB, STB) conquer the forest floor, others, such as BTB and CRB fly low closed to ground and high off from ground. The diet of babblers overlapped but they have broad diet breath to fulfil their need for nutrient and avoid competition. Despite Coleoptera being the most frequently encountered anthropod in babbler diets, caterpillar which was found to have the highest phosphorus content was the most preferred prey of babblers.

7.2 Limitations

Logistically, the study site is remote and accessible only by local-owned long boats or express boats. During peak season, where locals travel back to their villages in large numbers, transportation is difficult. National Park is difficult to access from the river due to steep bank, hilly terrain and lack of jungle trails that forcing the sampling to be taken place closed to the abandoned resort. Occurrence of the wild animals such as sunbears, at forest near National Park threaten the safety of researchers too.

7.3 Recommendations

Netting probability was low in this study. Changing the mist-nets every day perhaps could increase probability of netting them. Insectivorous birds do not eat all insects found in their habitat. Thus, adopting correct methods in capturing arthropods that constitute the bird's diet is important. In the context of this study, sticky traps are efficient in collecting great number of arthropods, while arthropods captured by pitfall traps and leaf litter target ground dwelling babbler prey accurately. More pitfall traps and greater area for leaf litter collection could have greater number of prey collected, if there are needed for further nutritional analysis.

An uninterrupted electric supply for extracting the prey item in leaf litter collection under the light source with the Bersele Funnel is required. As the duration on extraction is a constant variable, and no bias on the time spent on the extraction of all collection leaf litter collection.

As human population and capacity for resource exploitation increases, human-induced disturbance is inevitable. It is the level or degree of disturbance that sets them apart. Responses of wildlife, such as shown by birds to the disturbance, vary according

level, and sources. Knowledge of disturbance level in a habitat give insight to understanding community level adaptations that promote coexistence.

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APPENDICES

Appendix 1: Environmental assessment form applied at each station.

No.	Parameter	Replicate								
		1			2			3		
	A. Human Component									
1.1	Presence of human									
1.2	Presence of animal									
	B. Plant Component									
2.	Canopy gap %									
3.	List of planted and pioneer trees in 10m ² and the size of trees (DBH) cm									
		Sublot			Sublot			Sublot		
		1	2	3	1	2	3	1	2	3
4.	Depth of leaf litter(cm)									

Appendix 2: List of tree families found recorded in the sampling stations.

	PNP	PL100	PL500	PL1000	B100	B500	B1000	PR100	PR500	PR1000
Actinidiaceae								1		2
Alangiaceae							1			
Ampelidaceae						1				
Anacardiaceae	1		1				1	2	1	1
Anisophylleaceae	2									
Annonaceae							2			
Aquifoliaceae	1				1		4			
Bombacaceae		6	3			1				
Burseraceae	5		2				2			
Clusiaceae	1			3		1	5	1	2	
Dilleniaceae	1	2	17	8		5	8	3		3
Dipterocarpaceae	11	10	1	3			1	5	2	3
Euphorbiaceae	14	7	22	9	5	15	10	3	14	9
Fabaceae	1				1	1	2			
Fagaceae	4				1		6	1		1
Flacourtiaceae	1									
<i>Ixonanthaceae</i>	0	1					1			
Lauraceae	1		1	1	1	2	24			
Leguminose	0	1								
Loganiaceae	0						1			
Melastomataceae	0	2				1			1	2
Meliaceae	2	1								
Moraceae	3	6	2	4	1	5	7	2	1	5
Myristicaceae	4		2	5			2		1	2
Myrtaceae				2		4	4	1	3	

Appendix 2 continued

Palmae					1		1		
Polygalaceae			2		1	1			
Rosaceae	1								
Rubiaceae				6		1	1		
Sapindaceae	1	2	5	2		1	1	1	2
Sapotaceae	1	2			1				
Sterculiaceae						1			
Theacea						1			
Tiliaceae	1								
Ulmaceae	1					2			1
Verbenaceae		1	1	3	2	7			1

Appendix 3: Checklist of overall bird species recorded from the current study from all sampling stations in Pelagus, Kapit from December 2014 until December 2015. * Protected species under Laws of Sarawak: Wild Life Protection Ordinance 1998. ** Totally protected species under Laws of Sarawak: Wild Life Protection Ordinance 1998. # Endemic species

	Order/ Family / Identification	Scientific name	PNP	PL100	PL500	PL1000	B100	B500	B1000	PR100	PR500	PR1000
	Columbiformes											
	Columbidae											
1	Emerald Dove	<i>Chalcophaps indica</i>	1	1	0	0	0	2	0	0	0	0
	Caprimulgiformes											
	Podargidae											
2	Gould's Frogmouth	<i>Batrachostomus stellatus</i>	0	0	0	0	0	1	0	0	0	3
	Cuculiformes											
	Cuculidae											
3	Plantive Cuckoo	<i>Cacomantis merulinus</i>	0	0	0	0	0	2	0	1	0	0
4	Moustached Hawk-cuckoo	<i>Hierococcyx sparveroides</i>	1	0	0	0	0	0	0	0	0	0
5	Hodgson's Hawk-Cuckoo	<i>Hierococcyx fugax</i>	0	0	0	0	0	1	0	0	0	0
6	Drongo-cuckoo	<i>Surniculus lugubris</i>	0	0	0	0	0	1	0	0	0	0
	Strigiformes											
	Strigidae											
7	Reddish Scops Owl *	<i>Otus rufescens</i>	0	0	0	0	0	0	0	0	0	1

Appendix 3 continued

8	Rajah Scops Owl *	<i>Otus brookii</i>	0	0	0	0	1	0	0	0	0	0
Trogoniformes												
Trogonidae												
9	Scarlet-rumped Trogon	<i>Harpactes duvaucelii</i>	2	0	0	0	0	1	0	0	0	0
10	Diard's Trogon	<i>Harpactes diardii</i>	0	0	0	2	0	1	0	0	0	0
Piciformes												
Indicatoridae												
11	Malaysian Honeyguide	<i>Indicator archipelagus</i>	0	0	0	0	0	3	0	0	0	0
Picidae												
12	Rufous Piculet *	<i>Sasia abnormis</i>	2	2	0	3	4	5	3	0	2	2
13	Olive-backed Woodpecker *	<i>Dinopium rafflesii</i>	0	0	0	0	0	1	0	0	0	0
14	Rufous Woodpecker *	<i>Micropeternus brachyurus</i>	0	0	0	2	0	0	0	0	0	0
15	Buff-rumped Woodpecker *	<i>Meiglyptes tristis</i>	0	0	0	2	0	0	0	0	0	0
16	Buff-necked Woodpecker *	<i>Meiglyptes tukki</i>	3	1	0	1	1	2	1	3	1	1
17	Maroon Woodpecker *	<i>Blythipicus rubiginosus</i>	1	0	0	0	0	0	0	0	0	0
Rhampatidae												
18	Red-crowned Barbet	<i>Megalaima rafflesii</i>	1	0	0	0	0	1	0	1	0	0
19	Red-throated Barbet	<i>Megalaima mystacophanos</i>	0	0	0	1	0	1	0	0	0	0
20	Blue-eared Barbet	<i>Megalaima australis</i>	0	0	0	0	0	0	0	0	0	1

Appendix 3 continued

Coraciiformes												
Alcedinidae												
21	Rufous-backed Kingfisher *	<i>Ceyx rufidorsa rufidorsa</i>	5	4	0	9	1	2	1	5	2	4
22	Blue-banded Kingfisher *	<i>Alcedo euryzona</i>	0	0	0	1	0	0	0	0	0	0
23	Blue-eared Kingfisher *	<i>Alcedo meninting</i>	0	0	0	0	4	0	0	0	0	0
24	Common Kingfisher *	<i>Alcedo atthis</i>	0	1	0	0	0	0	0	0	0	0
25	Banded Kingfisher *	<i>Lacedo pulchella</i>	0	1	0	0	0	0	0	0	0	1
26	Rufous-collared Kingfisher *	<i>Actenoides concretus</i>	0	0	0	2	0	0	0	0	3	0
Passeriformes												
Pittidae												
27	Blue-winged Pitta **	<i>Pitta moluccensis</i>	0	3	0	0	0	0	0	1	0	0
Eurylaimidae												
28	Black-and-red Broadbill	<i>Cymbirhynchus macrorhynchos</i>	0	2	0	0	1	0	0	0	0	0
29	Black-and-yellow Broadbill	<i>Eurylaimus ochromalus</i>	0	0	1	0	0	1	0	0	0	0
Calyptomenidae												
30	Green Broadbill	<i>Calyptomena viridis</i>	3	2	1	2	0	4	2	0	0	3
Vangidae												
31	Rufous-winged Philentoma	<i>Philentoma pyrrhoptera</i>	4	0	0	1	0	0	0	0	1	1

Appendix 3 continued

Dicruridae												
32	Bronze Drongo	<i>Dicrurus aeneus</i>	1	1	0	0	0	1	0	0	0	0
Rhipiduridae												
33	Pied Fantail	<i>Rhipidura javanica</i>	0	0	0	0	0	0	0	2	1	0
Corvidae												
34	Crested Jay	<i>Platylophus galericulatus</i>	0	0	0	1	0	0	0	0	0	0
Monarchidae												
35	Black-naped Monarch	<i>Hypothymis azurea</i>	2	3	5	2	2	5	4	1	5	6
36	Indian Paradise-flycatcher *	<i>TerPphone paradisi</i>	0	1	0	0	3	2	2	0	0	0
Dicaeidae												
37	Yellow-breasted Flowerpecker	<i>Prionochilus maculatus</i>	5	6	0	4	7	6	2	5	6	2
38	Scarlet-backed Flowerpecker	<i>Prionochilus thoracicus</i>	0	0	0	0	0	0	0	2	0	0
39	Yellow-rumped Flowerpecker#	<i>Prionochilus xanthopygius</i>	3	1	0	6	1	9	11	1	6	8
40	Crimson-breasted Flowerpecker	<i>Prionochilus percussus</i>	1	0	0	0	0	0	0	0	0	1
41	Orange-bellied Flowerpecker	<i>Dicaeum trigonostigma</i>	3	0	2	1	2	0	0	3	1	2
42	Plain Flowerpecker	<i>Dicaeum concolor</i>	0	0	0	0	0	2	0	0	0	0

Appendix 3 continued

Nectariniidae												
43	Thick-billed Spiderhunter	<i>Arachnothera crassirostris</i>	1	0	0	0	0	0	0	0	0	0
44	Little Spiderhunter	<i>Arachnothera longirostra</i>	24	26	26	33	21	32	5	13	41	25
45	Yellow-eared Spiderhunter	<i>Arachnothera chrysogenys</i>	0	0	0	0	0	0	0	0	0	2
46	Spectacled Spiderhunter	<i>Arachnothera flavigaster</i>	2	0	0	0	0	0	0	0	0	1
47	Grey-breasted Spiderhunter	<i>Arachnothera modesta</i>	1	0	0	0	0	0	0	1	0	0
48	Streaky-breasted Spiderhunter	<i>Arachnothera everetti</i>	0	2	0	0	2	0	0	0	0	0
49	Purple-naped Sunbird	<i>Kurochkinogramma hypogrammicum</i>	12	2	0	6	3	9	4	2	3	5
50	Ruby-cheeked Sunbird	<i>Chalcoparia singalensis</i>	0	2	0	0	0	0	1	0	0	0
51	Plain Sunbird	<i>Anthreptes simplex</i>	4	0	1	0	0	4	1	0	0	9
52	Brown-throated Sunbird	<i>Anthreptes malacensis</i>	4	1	0	0	3	1	0	1	0	4
53	Red-throated Sunbird	<i>Anthreptes rhodolaemus</i>	0	0	0	0	0	1	0	0	0	1
54	Olive-backed Sunbird	<i>Cinnyris jugularis</i>	0	1	0	0	0	2	0	2	0	0
55	Temminck's Sunbird	<i>Aethopyga temminckii</i>	0	1	0	0	0	0	0	0	0	0
56	Crimson Sunbird	<i>Aethopyga siparaja</i>	0	0	0	1	0	1	0	0	1	0

Appendix 3 continued

Irenidae												
57	Asian Fairy-bluebird	<i>Irena puella</i>	1	0	0	1	0	2	0	0	0	1
58	Greater Green Leafbird	<i>ChloroΨs sonnerati</i>	0	0	0	0	0	1	0	0	0	1
59	Lesser Green Leafbird	<i>ChloroΨs cyanopogon</i>	0	1	0	0	1	0	0	0	0	4
60	Blue-winged Leafbird	<i>ChloroΨs cochinchinensis</i>	0	1	0	0	0	0	0	0	0	2
Estrildidae												
61	Dusky Munia#	<i>Lonchura fuscans</i>	0	1	0	0	0	0	0	5	2	3
62	Pin-tailed Parrotfinch	<i>Erythrura prasina</i>	0	1	0	0	0	0	0	0	0	0
Cisticolidae												
63	Rufous-tailed Tailorbird	<i>Orthotomus sericeus</i>	1	6	0	0	8	2	0	12	0	0
Pycnonotidae												
64	Hairy-backed Bulbul	<i>Tricholestes criniger</i>	4	0	6	3	0	4	1	0	8	1
65	Grey-cheeked Bulbul	<i>Alophoixus bres</i>	5	3	3	3	0	2	5	2	4	3
66	Yellow-bellied Bulbul	<i>Alophoixus phaeocephalus</i>	5	0	0	5	0	0	0	0	0	0
67	Buff-vented Bulbul	<i>Iole charlottae</i>	0	1	2	1	0	3	1	0	1	7
68	Grey-bellied Bulbul	<i>Pycnonotus cyaniventris</i>	1	0	0	0	0	0	0	0	0	0
69	Yellow-vented Bulbul	<i>Pycnonotus goiavier</i>	0	1	0	0	0	0	0	0	0	0
70	Olive-winged Bulbul	<i>Pycnonotus plumosus</i>	0	4	1	0	2	5	0	7	1	3

Appendix 3 continued

71	Cream-vented Bulbul	<i>Pycnonotus simplex</i>	0	2	0	0	1	4	0	0	0	3
72	Red-eyed Bulbul	<i>Pycnonotus brunneus</i>	1	2	0	1	0	4	1	0	1	3
73	Spectacled Bulbul	<i>Pycnonotus erythrophthalmos</i>	2	2	0	3	0	12	0	0	4	20
74	Puff-backed Bulbul	<i>Euptilotus eutilotus</i>	6	6	0	0	6	7	0	0	5	5
75	Black-and-white Bulbul	<i>Microtarsus melanoleucos</i>	2	0	0	0	0	5	1	0	0	2
76	Black-headed Bulbul	<i>Brachypodius atriceps</i>	0	9	2	0	1	2	0	1	0	0
Phylloscopidae												
77	Artic Warbler	<i>Seicercus borealis</i>	0	0	0	0	0	0	0	0	1	0
Zosteropidae												
78	Chestnut-crested Yuhina	<i>Yuhina everetti</i>	0	0	0	0	0	9	0	0	0	0
Timaliidae												
79	Chestnut-backed Scimitar Babbler	<i>Pomatorhinus montanus</i>	0	0	0	0	0	0	0	0	2	0
80	Black-throated Babbler	<i>Stachyris nigricollis</i>	1	2	3	2	2	3	0	4	2	7
81	Chestnut-rumped Babbler	<i>Stachyris maculata</i>	0	0	0	2	0	0	1	0	2	2
82	Grey-headed Babbler	<i>Stachyris poliocephala</i>	0	8	4	6	2	2	1	0	1	1
83	Striped Tit-babbler	<i>Mixornis gularis</i>	0	1	0	0	0	0	0	1	0	0
84	Fluffy-backed Tit-babbler	<i>Macronus ptilosus</i>	3	2	1	1	2	3	3	1	2	7
85	Chestnut-winged Babbler	<i>Cyanoderma erythropteron</i>	6	7	8	4	6	7	5	3	2	17

Appendix 3 continued

Pellorneidae												
86	Sooty-capped Babbler	<i>Malacopteron affine</i>	5	1	0	3	0	0	3	3	2	1
87	Scaly-crowned Babbler	<i>Malacopteron cinereum</i>	5	0	0	3	0	1	4	1	1	1
88	Rufous-crowned Babbler	<i>Malacopteron magnum</i>	4	1	0	1	0	0	0	0	0	4
89	Moustached Babbler	<i>Malacopteron magnirostre</i>	2	0	0	1	0	0	0	0	0	1
90	Black-capped Babbler	<i>Pellorneum capistratum</i>	5	1	2	0	2	0	0	1	0	2
91	Short-tailed Babbler	<i>Trichastoma malaccense</i>	11	5	0	7	2	2	4	6	4	11
92	Ferruginous Babbler	<i>Trichastoma bicolor</i>	1	3	1	8	0	2	1	2	0	1
93	White-chested Babbler	<i>Trichastoma rostratum</i>	0	5	0	2	4	1	2	4	2	7
94	Horsfield's Babbler	<i>Malacocincla sepiaria</i>	0	1	1	1	0	0	0	0	1	0
Muscicapidae												
95	White-rumped Shama *	<i>Kittacincla malabarica</i>	4	2	0	4	4	2	0	2	3	2
96	Bornean Blue Flycatcher#	<i>Cyornis superbus</i>	5	2	2	0	1	0	0	7	3	1
97	Malaysian Blue flycatcher	<i>Cyornis turcosus</i>	0	2	0	0	2	1	0	3	2	0
98	White-tailed Blue Flycatcher	<i>Cyornis concretus</i>	1	0	0	0	0	0	0	0	0	0
99	Grey-chested Jungle Flycatcher	<i>Cyornis umbratilis</i>	0	0	0	0	0	1	2	0	1	0
100	Brown-chested Jungle Flycatcher	<i>Cyornis brunneatus</i>	0	0	0	2	0	3	2	0	0	0
101	Siberian Blue Robin	<i>Larvivora cyane</i>	0	0	0	1	0	0	0	0	0	0

Appendix 3 continued

102	Chestnut-naped Forktail	<i>Enicurus ruficapillus</i>	0	0	0	0	1	0	3	0	1	3
103	Little pied Flycatcher	<i>Ficedula westermanni</i>	0	0	0	0	0	0	1	0	0	0
104	Yellow-rumped Flycatcher	<i>Ficedula zanthopygia</i>	0	0	0	1	0	0	0	0	0	0
105	Rufous-chested Flycatcher	<i>Ficedula dumetoria</i>	1	0	0	3	1	0	0	0	0	0
106	Pygmy Blue Flycatcher	<i>Ficedula hodasoni</i>	2	0	0	1	0	0	0	0	0	0

Appendix 4: Frequency of each species caught at respective shelf.

No.	IDENTIFICATION	Shelf					
		1	2	3	4	5	6
	Columbidae						
1	Emerald Dove	1	0	2	0	1	0
	Podargidae						
2	Gould's Frogmouth	1	1	2	1	1	0
	Cuculidae						
3	Plantive Cuckoo	1	0	1	0	1	0
4	Javan Hawk Cuckoo	0	0	0	1	0	0
5	Moustached Hawk-cuckoo	0	0	0	0	1	0
6	Drongo-cuckoo	0	1	0	0	0	0
	Strigidae						
7	Reddish Scops Owl	1	0	0	0	0	0
8	Rajah Scops Owl	0	0	0	1	0	0
	Trogonidae						
9	Scarlet-rumped Trogon	0	0	1	2	0	1
10	Diard's Trogon	0	1	2	0	0	0
	Indicatoridae						
11	Malaysian Honeyguide	0	0	0	1	2	0
	Picidae						
12	Rufous Piculet	3	5	8	7	2	0
13	Olive-backed Woodpecker	0	0	0	1	0	0
14	Rufous Woodpecker	0	0	1	1	0	0
15	Buff-rumped Woodpecker	0	0	2	0	0	0
16	Buff-necked Woodpecker	3	3	4	3	1	0
17	Maroon Woodpecker	0	0	0	0	2	0
	Rhampatisdae						
18	Red-crowned Barbet	0	1	0	1	1	0
19	Red-throated Barbet	0	0	1	1	2	0
20	Blue-eared Barbet	0	0	1	0	0	0
	Alcedinidae						
21	Rufous-backed Kingfisher	9	6	17	9	5	3
22	Blue-banded Kingfisher	0	0	1	0	0	0
23	Blue-eared Kingfisher	1	2	0	1	0	0
24	Common Kingfisher	0	0	0	1	0	0
25	Banded Kingfisher	0	1	1	0	0	0
26	Chestnut-collared Kingfisher	1	0	2	1	1	0
	Pittidaea						
27	Blue-winged Pitta	0	2	0	2	1	1

Appendix 4 continued

Eurylaimidae							
28	Black-and-red Broadbill	0	1	1	0	1	0
29	Black-and-yellow Broadbill	0	0	1	0	0	1
Calypomenidae							
30	Green Broadbill	1	2	5	4	3	2
Vangidae							
31	Rufous-winged Philentoma	1	2	1	1	0	0
Dicruridae							
32	Bronzed Drongo	0	1	0	2	0	1
Rhipiduridae							
33	Pied Fantail	2	0	1	1	1	0
Corvidae							
34	Crested Jay	1	0	0	0	0	0
Monarchidae							
35	Black-naped Monarch	3	5	9	9	5	1
36	Indian Paradise-flycatcher	0	1	1	2	1	2
Dicaeidae							
37	Yellow-breasted Flowerpecker	4	5	16	11	12	6
38	Scarlet-backed Flowerpecker	0	1	1	0	0	0
39	Yellow-rumped Flowerpecker	9	6	17	14	12	6
40	Crimson-breasted Flowerpecker	0	0	1	1	0	0
41	Orange-bellied Flowerpecker	1	2	3	2	7	0
42	Plain Flowerpecker	1	0	0	0	1	0
Nectariniidae							
43	Thick-billed Spiderhunter	0	1	0	0	0	0
44	Little Spiderhunter	22	81	106	58	35	10
45	Yellow-eared Spiderhunter	0	0	0	0	1	0
46	Spectacled Spiderhunter	0	0	2	1	0	0
47	Grey-breasted Spiderhunter	0	0	1	0	1	0
48	Streaky-breasted Spiderhunter	0	0	3	0	0	0
49	Purple-naped Sunbird	6	18	19	10	5	1
50	Ruby-cheeked Sunbird	0	0	0	0	2	1
51	Plain Sunbird	3	5	5	1	2	3
52	Brown-throated Sunbird	0	4	4	5	2	0
53	Red-throated Sunbird	0	0	0	0	0	1
54	Olive-backed Sunbird	0	1	1	0	0	0
55	Temminck's Sunbird	0	0	0	0	1	0
56	Eastern-crimson Sunbird	0	0	2	0	0	0

Appendix 4 continued

Irenidae							
57	Asian Fairy Bluebird	0	0	2	2	1	0
58	Greater Green Leafbird	0	0	0	1	1	0
59	Lesser Green Leafbird	0	2	2	3	0	0
60	Blue-winged Leafbird	0	0	1	0	1	0
Estrildidae							
61	Dusky Munia	0	2	4	2	1	0
62	Pin-tailed Parrotfinch	0	0	0	0	0	1
Cisticolidae							
63	Rufous-tailed Tailorbird	8	8	6	4	3	0
Pycnonotidae							
64	Hairy-backed Bulbul	1	5	13	4	2	0
65	Grey-cheeked Bulbul	3	2	8	15	4	5
66	Yellow-bellied Bulbul	0	0	3	5	2	1
67	Buff-vented Bulbul	0	2	7	5	2	1
68	Grey-bellied Bulbul	0	0	1	0	0	0
69	Yellow-vented Bulbul	0	0	0	0	0	1
70	Olive-winged Bulbul	0	1	15	5	2	1
71	Cream-vented Bulbul	1	1	4	4	0	1
72	Red-eyed Bulbul	1	0	5	5	3	2
73	Spectacled Bulbul	2	5	11	15	11	4
74	Puff-backed Bulbul	1	5	17	12	6	1
75	Black and White Bulbul	2	0	4	4	1	0
76	Black-headed Bulbul	1	3	6	3	3	1
Phylloscopidae							
77	Artric Warbler	0	0	0	0	1	0
Zosteropidea							
78	Chestnut-crested Yuhina	0	2	5	2	0	0
Timaliidae							
79	Chestnut-backed Scimitar Babbler	0	1	0	1	0	0
80	Black-throated Babbler	6	8	11	0	1	1
81	Chestnut-rumped Babbler	1	2	2	1	0	6
82	Grey-headed Babbler	9	8	6	4	0	0
83	Striped Tit-babbler	0	0	0	1	0	0
84	Fluffy-backed Tit-babbler	6	8	6	1	1	0
85	Chestnut-winged Babbler	24	19	12	9	6	0
Pellorneidae							
86	Sooty-capped Babbler	3	8	4	2	0	1
87	Scaly-crowned Babbler	6	5	3	2	0	0

Appendix 4 continued

88	Rufous-crowned Babbler	5	2	2	0	1	0
89	Moustached Babbler	1	0	1	0	2	0
90	Black-capped Babbler	4	5	2	2	0	0
91	Short-tailed Babbler	35	13	4	4	2	1
92	Ferruginous Babbler	5	5	4	4	2	1
93	White-chested Babbler	2	13	8	5	1	0
94	Horsfield's Babbler	1	1	0	2	2	0
Muscicapidae							
95	White-rumped Shama	3	8	5	5	4	0
96	Bornean Blue Flycatcher	4	6	5	3	1	0
97	Malaysian Blue Flycatcher	1	2	2	3	2	0
98	White-tailed Flycatcher	0	1	0	0	0	0
99	Grey-chested Jungle Flycatcher	2	3	3	0	0	1
100	Brown-chested Jungle Flycatcher	2	2	2	0	0	0
101	Siberian Blue Robin	1	0	0	0	0	0
102	Chestnut-naped Forktail	2	3	0	3	0	0
103	Little Pied Flycatcher	0	0	0	0	0	1
104	Rufous-chested Flycatcher	2	1	1	0	0	1
105	Yellow-rumped Flycatcher	0	1	1	0	0	0
106	Pygmy Blue Flycatcher	0	2	1	0	0	0
Frequency		176	258	288	170	114	44
Species		51	61	74	64	58	34

Appendix 5: Research permits

08-DEC-2014 15:51 FROM NCCD

TO SG3505

P.05/05



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

Permit No: 467/2014

Permission is hereby given Ms. Pang Sing Tyan, Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak
NRIC/Passport No: 811226-12-5308

And the following persons, namely —

1. Atiqah Fadillah Sapian	NRIC/Passport No: 890629-13-5330
2. Khatijah Ismail	NRIC/Passport No: 900911-13-6544
3. Mohd Hasri Al Hasri Haba	NRIC/Passport No: 821210-13-5199
4. Rahah Mohd Yakup	NRIC/Passport No: 790326-13-5626
5. Isa Salt	NRIC/Passport No: 620514-1335891

To enter Pelagus National Park in Sarawak and to:-

- | | |
|---|---|
| (a) exercise a subsisting right/privilege, namely | |
| (b) conduct a special activity, namely | |
| (c) conduct a research activity, namely | <i>Diet And Diversity Of Babilers
(Sylvioidea Iii): Possible Effects
Of Disturbance Gradienst At
Pelagus, Central Sarawak (East
Malaysia: Borneo)</i> |
| (d) conduct an expedition, namely | |
| (e) conduct a filming work, namely | |

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

Date of Issue : 31.10.2014
Valid Until (date) : 30.10.2015

Fees paid (RM) : Waived entrance fee

Signature:

Name: HAJI WAN SHARDINI BIN WAN SALLEH

Official Stamp:
for Controller of National Parks & Nature Reserves

- N.F.1. This permit shall be returned to the Controller or any authorized Park Officer upon its expiration, cancellation or withdrawal.
2. This permit must be produced for inspection at any time on demand by the Controller or any authorized Park Officer.
(Special conditions attached)

*Delete wherever applicable.

TOTAL P.05

Appendix 5 continued



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

Permit No: 462/2015

Permission is hereby given **Ms. Pang Sing Tyan, Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak**
 NRIC/Passport No: **811226-12-5308**
 And the following persons, namely —

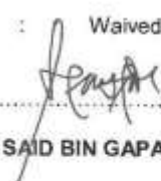
1. Attiqqah Fadzillah binti Sopian	NRIC/Passport No: 890629-13-5330
2. Khatijah Ismail	NRIC/Passport No: 900911-13-6544
3. Mohd Hasri Al Hasri Haba	NRIC/Passport No: 821210-13-5199
4. Rahah Mohd Yakup	NRIC/Passport No: 790326-13-5626
5. Isa Sait	NRIC/Passport No: 620514-13-5891

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

- | | |
|--|--|
| (a) ~~exercise a subsisting right/privilege, namely~~ | |
| (b) ~~conduct a special activity, namely~~ | |
| (c) ~~conduct a research activity, namely~~ | <i>Diet And Diversity Of
Babblers (Sylvioidea iii)
Possible Effects Of
Disturbance Gradienst At
Pelagus, Central Sarawak
(East Malaysia: Borneo)</i> |
| (d) ~~conduct an expedition, namely~~ | |
| (e) ~~conduct a filming work, namely~~ | |

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

Date of Issue : **23.11.2015**
 Valid Until (date) : **22.11.2016**
 Fees paid (RM) : Waived entrance fee

Signature: 
 Name: **HAJI SAID BIN GAPAR**



Official Stamp:
 for Controller of National Parks & Nature Reserves

- N.R.1. This permit shall be returned to the Controller or any authorized Park Officer upon its expiration, cancellation or withdrawal.
2. This permit must be produced for inspection at any time on demand by the Controller or any authorized Park Officer.
 (Special conditions attached)

*Delete wherever inapplicable.

Appendix 6: List of Publications

- Pang, S. T., Sopian, A. F., Ismail, K., & Jhin, K. O. K. C. Z. E. (2018). Diet of passerine birds from different habitat types in Sarawak, Borneo. *Malaysian Applied Biology*, 47, 239–246.
- Attiqqah, F. S., Mohd. Azlan, J., Khatijah, I., Pang, S.-T., Rahah, M. Y., Mohd. Hasri, H. A. H., Sait, I. and Tuen, A. A. (2018). Diversity and functional guild of understorey birds in different types of forest in Ulu Baram. *Malaysian Applied Biology*, 47, 153–158.
- Pang, S. T., Attiqqah, F. S., Khatijah, I., Rahah, M. Y., Mohd-Hasri, A. H. H., Isa, S., & Tuen, A. A. (2017). The use of tartar emetic to study the diet of insectivorous birds in Borneo. *Malaysian Applied Biology*, 46(2), 153–156.
- Pang, S. T., Sopian, A. F., Ismail, K., & Tuen, A. A. (2017). Aboveground space utilization and feeding guild of tropical rainforest birds in Sarawak , Borneo. *Transactions on Science and Technology*, 4(4), 504–512.
- Pang, S. T., Frances, H. D. S., Audrey, V. M. F., Hanis, D. E. L., Mary, B. B., Luisa, D. S., ... Tuen, A. A. (2017). Birds. In Mohd-Azlan, J., Tuen, A. A. & Das, I. (Eds.), *Life from headwaters to the coast Gunung Penrissen The Roof of Western Borneo* (pp. 112–127). UNIMAS Publisher and Natural History Publications (Borneo).