CHAPTER 1

INTRODUCTION

1.1 Tropical rainforest

Tropical rainforest is the most productive forest that contain highly diversified flora and fauna (Mohamed Zakaria, 2002, Mohamed Zakaria, 2005, Ramli, 2010, Wan Razali, 2012). The forest is a home for most wildlife species which are depending on healthy forest ecosystem that can provide basic needs for survival such as shelter, food resources and breeding ground (Zamri, 2002). Lowland rainforest is one of the major forest type in Malaysia (WWF, 2012). It contains highly diversified and complex ecosystem which dominated by family Dipterocarpaceae (Strange, 1993). The forest begins at sea level and extends up to an altitude of 750 m where the lower montane forest begins (Whitmore, 1975). Four distinct vertical zonations existed in lowland forest; these are lower storey, middle storey, canopy and emergent. Based on this criteria, the lowland forest are able to harbor more species as compared to other forest types (Ramli, 2010).

Each vertical zonation support different species of flora and fauna. The lower storey comprises of small woody plants, tree saplings, small palms and ferns. The humidity is higher at this level due to low light penetration. The trunks of big trees and the crowns of smaller trees form the middle storey. The canopy consists of closely joined crown of huge trees, thick-stemmed lianas, rattans and fan palms, stands at 20-40 meter above the ground. The emergent trees can reach up to 60-70 meter usually comprises of individuals from the family Dipterocarpaceae. This level absorb about 60% of the light thus decrease the humidity during daylight (Wong, 1980).

The vertical zonation of primary forest is distinguishable with sparse undergrowth as a result of low sunlight penetration to the forest floor. Primary forest is naturally forest of native species. It is not affected by any human activities and its ecological processes is still undisturbed (FAO, 2010). Example of this forest in Malaysia include Virgin Jungle Reserve (VJR), National Park and Wildlife Bird Sanctuary. In contrast to primary forest, the vertical zonation of the secondary forest is not clearly distinguish and floristically poorer. Forest gaps were created in the canopy as a result of logging activities. More sunlight penetrated forest floor and allowing fast-growing herbs, lianas, saplings, and branches of bordering trees to quickly filled the forest gap (Schemske and Brokaw, 1981). Bamboo clumps thrive as the result of logging and it became the characteristics feature of disturbed forest (Jeyarasingam, 1998). Some bird species like Pin-tailed Parrotfinch *(Erythrura prasina)* depend on bamboo seed as their main food resource.

Lowland forest that contains various types of flora and fauna are valuable for scientific research and wildlife conservation. Heavy utilization of forest natural resources for economic purposes (timber exploitation and land used for plantation) become major threat to the ecosystem (Thinh et al., 2012b). Deforestation is the main issue of developing countries including Malaysia in supporting the basic needs of increasing human population (FAO, 2010; Wan Razali, 2012). Approximately five million hectares of forest cover in Malaysia (about four times of Singapore) have been reduced from 1983 to 2003 (WWF, 2012). Loss of habitat become serious threat to tropical forest birds which are dependable on healthy forest ecosystem (Zakaria et al., 2005).

Forestry Department of Malaysia had developed undisturbed forest network called Virgin Jungle Reserve (VJR) since 1947. The forest was preserved strictly for research purposes including biodiversity and genetic conservation. In Peninsular Malaysia, there are 120 VJRs that cover an area of 111,800 hectares that have been established (Chan, 2002). These forests function as local refugia which helped forest-interior species to survive in harsh environment especially when it is connected with logged forests that support conservation of flora and fauna, important for educational and recreational purposes. Primary forest is considered as fragile ecosystem because it harbor higher density of rare species (Sodhi et al., 2005).

1.2 Community structure of birds in lowland forest

Approximatley 662 species of birds are recorded in Peninsular Malaysia (MNS, 2010). Of overall species, 67% (445 species) are resident, 28% (184 species) are migrants and 5% (38 species) have both resident and migratory populations. Forest associated species formed biggest proportions of total species represented by 467 species that belong to 54 families, followed by 151 aquatic species that belong to 27 families and 44 predator species belong to three families (MNS, 2010). Approximately 311 bird species occupy lowland forest in Malaysia and the habitat can harbor more bird species than degraded habitat (Ramli, 2010).

The avifauna is known as one of the taxon that are particularly rich in lowland rainforest (Strange, 1993, Ramli, 2010). Community structure of birds is varied due to variation in habitat structure, availability of food resources, microclimate changes and spatial variation. Each family and species occupies certain niche within the four vertical zonations (Strange, 1993). The lower and middle story frequently dominated by bulbuls

(Pycnonotidae) and babblers (Timaliidae). Among these family, genera *Trichastoma*, *Malacopteron* and *Stachyris* are the most abundant (Jeyarasingam, 1998). *Trichastoma* prefers lower storey and rarely penetrate the middle strorey where *Malacopteron* and *Stachyris* are more abundant. On the contrary, flycatchers (Muscicapidae), spiderhunters and sunbirds (Nectariniidae), trogons (Trogonidae), and pigeons (Columbidae) prefer to forage in the middle storey while ioras and leafbirds (Chloropsidae) frequent the canopy. Raptors (Accipitridae) frequent the canopy but it may come down to middle storey for hunting.

Bird prefers healthy forest ecosystem that provide food resources, good nesting sites with less competition, and safe from predators. Peh (2005) reported high diversity of forest birds in primary forest compared to degraded habitat. The undisturbed habitat was dominated by forest-dependent species such as babblers (Mohamed Zakaria, 2002). Secondary forest may also recorded higher species richness due to domination of secondary or colonizer species such as spiderhunters and bulbuls (Nagata, 1997). The secondary forest-dependant species which has a wide range of tolerance utilized resources available at the forest edge of primary forest especially when located adjacent to the degraded habitat. Forest birds might be able to occupy intact secondary forest after sufficient period of forest regeneration.

1.3 Ecological importance of birds in tropical forest

Birds play important roles (in maintaining ecological processes) as predators, prey, seed dispersers and pollinators (Pimm, 1986). Study in Western Ghats, India had proven that avian species were the most common seed dispersal agents (59%) compared to mammals (26%) (Ganesh and Davidar, 2001). Seed dispersers and pollinators are crucial in disturbed habitat since they assist in forest regeneration. Birds especially frugivores were the most important seed dispersers in tropical forest and their preference for specific habitats may influence seed dispersal patterns (Gomes, 2008). The dispersal capability may help in germination, spatial distribution, genetic structure patterns for many plant species (Gomes, 2002). Occurrences of fig trees (*Ficus* sp) in lowland rainforest is closely related to the movement of frugivorous birds from one habitat to another (Strange, 1993). Birds dropping may help to deposite the seeds of figs (*Ficus* sp) on branches of another tree.

Birds can be environmental indicators because of their sensitivity to small changes in habitat structure and composition (Owiunji and Plumptre, 1998, Peh, 2005). Several group of birds such as babblers and bulbuls can be used as an indicator groups for evaluating degree of habitat disturbances (Hisashi Nagata, 1997, Owiunji and Plumptre, 1998, Mohamed Zakaria, 2002, Mohamed Zakaria, 2005). Frugivores like bulbuls and sunbirds form a mobile link and normally abundant at forest edge and/or in forest gaps. Generalist species such as Little Spiderhunter (*Arachnothera longirostra*) and endemic species such as White-breasted Babbler (*Stachyris grammiceps*) were used to test resilience level in degraded habitat of central Java (Sodhi et al., 2005). In addition, pollination of some flowering species is assisted by nectarivores species such as spiderhunters, sunbirds and flowerpeckers. Predator species such as Falconidae (eagles,

hawks) and Strigidae (owls) act as predator in controlling pest population in plantations, cultivation and lowland forest.

1.4 Factors influence bird diversity in lowland forest

1.4.1 Habitat variation

Logging activities had caused reduction of forested area, increased isolation among fragments and creating forest edge (Sekercioglu and Sodhi, 2007). Changes in habitat have influenced community structure of understorey birds (Sekercioglu, 2002, Peh, 2005, Sodhi, 2007) which are very sensitive towards habitat changes. It also affected sedentary, rare and restricted-range birds, rainforest habitat specialist and altitudinal migrants especially in small fragmented areas (Raman and Sukumar, 2002). Losing 90% of primary habitat may lead to approximately 25-50% birds species extinction (Sekercioglu and Sodhi, 2007). Poor resilience to disturbances makes the affected species prone to extinction although certain degraded habitats such as logged forest can harbor a proportion of primary birds (Sodhi et al., 2005).

Understorey birds such as babblers and bulbuls are highly sensitive to selective logging therefore it can be a suitable indicator for forest regeneration following logging (Johns, 1989, Hisashi Nagata, 1997, Owiunji and Plumptre, 1998, Mohamed Zakaria, 2002, Peh, 2005, Mohamed Zakaria, 2005). Sensitivity of birds to fragmentation correlates strongly to ecological traits of a species such as body size, diet, mobility and specialization. Many studies have been developed to investigate the effects of logging on tropical bird communities inhabiting lowland rainforest (Johns, 1986, Johns, 1989, Owiunji and Plumptre, 1998, Peh, 2005, Sodhi et al., 2005, Mohamed Zakaria, 2005, Sodhi, 2007, Dent, 2009, Thinh et al., 2012b). Forests in early stages of regeneration (less

than ten-years old) will have low abundance and richness compared to primary forest. Abundance of primary forest birds were decreased when the habitat was shifted from primary to logged forests and being replaced by numerous number of colonizer species (Mohamed Zakaria, 2005). Some species inhabit primary forest may persist or reappear in logged forest although the abundance may not be the same as unlogged forest (Johns, 1989).

Sodhi (2007) reported that many forest species in a forest patch of Singapore were lost and being replaced by introduced species such as house crow (*Corvus splendens*). Remaining native species are expected to be extinct from the area due to competition and predation by introduced species. Forest birds are unable to survive in small forest fragment and will significantly declined over time and replaced by introduced species (Sodhi, 2007). Formation of roads in forested areas become habitat barrier that inhibit the movement of forest-interior species. Roads may increase habitat fragmentation, habitat disturbances and change species composition (Thinh et al., 2012a). The movement of understorey species e.g members of family Timaliidae across the road was reduced compared to forest interior, but not for mid-storey species such as Striped tit-babbler (*Macronus gularis*) (Thinh et al., 2012a).

Larger birds are prone to be extinct compared to smaller species in small and fragmented habitats due to the requirement of bigger area and high food intake (Sodhi, 2004). Previous study in primary forest of Pasoh Forest Reserve and disturbed forest of Ulu Gombak Forest Reserve shows that larger babblers were found mainly in primary forest but lacking from disturbed forest (Nagata, 1997). This suggested that habitat destruction has an adverse effect on large babblers which need larger undisturbed areas to increase the survival of its low population. Smaller fragments also cannot provide large

requirements of territories for behaviorally specialized species that formed mixed-species flocks during foraging (Sodhi, 2007, Loures-Ribeiro et al., 2011).

1.4.2 Food availability

Food abundance is an important factor of avian phenology which can be affected by logging activities (Yap et al., 2007). Breeding cycles and molting occurrences of highly sensitive understorey birds such as insectivorous depending on availability of food resources such as arthropod, fruit and flower (Yap et al., 2007). Availability of resources are influenced by environmental changes (Loures-Ribeiro et al., 2011). Forest birds are more affected by habitat disruption than non-forest birds, and among insectivorous species compared to other feeding guilds for example carnivorous, frugivorous, nectarivorous, and granivorous (Sekercioglu, 2002, Sodhi, 2007, Loures-Ribeiro et al., 2011).

Forest understorey insectivores are particularly sensitive to habitat changes and fragmentation (Sekercioglu, 2002). Generally, species with high habitat specificity and low mobility are confined to forest-interior, therefore it was sensitive towards habitat changes. Diversity of insectivorous species was significantly low in smaller fragments and degraded habitat due to declining of prey resources, poor dispersal abilities and intolerant to non-forest matrix surrounding the fragments (Sekercioglu, 2002). Terrestrial and arboreal foliage gleaning insectivores species are vulnerable to microclimate changes because of poor adaptation to habitat changes and affected food resources (Zakaria, 2001). Abundance of bark-associated insectivores bird such as woodpecker was low in logged forest which had undergone recovery process for 12 years (Johns, 1989)

Formation of forest gap (whether naturally or man-made) had created different physical environment between gap phase and mature forest understorey which contributed to differences in bird community structure (Levey, 1988). Concentration of numerous resources in forest gap may attract more species especially forest-edge species to occupy the space (Schemske and Brokaw, 1981, Levey, 1988). Increasing in formation of forest edges may affect movement of understorey species especially forest-interior species. Forest-interior species avoided forest edges due to intolerant to higher temperature and food scarcity (Loures-Ribeiro et al., 2011). Some forest species were able to utilize food resources in adjacent secondary forest. However, the number of specialist may increase as secondary forest aged due to increased in fruit resources (Sodhi, 2007).

Higher abundance of frugivorous and nectarivorous were recorded in logged forest due to open canopy and extensive growth of understorey vegetation (Owiunji and Plumptre, 1998). Generalist frugivores are less likely to be affected by local variation in forest interior, however the consequences might affect specialist frugivores (Gomes, 2002). Generalist species attracted more to forest edges and habitat near roads due to their capability to adapt with habitat changes for example high light intensity (Thinh et al., 2012a). Specialist frugivores may become vulnerable in disturbed habitats or small fragments due to incapability of such areas in providing sufficient volume of fruits.

Frugivores may become important dispersal agent and its loss may have an effect on the functioning of forest ecosystem (Levey, 1988). Their ecological roles strongly depends on their capability to withstand habitat disturbances (Gomes, 2008). Frugivorous species can be affected by variation in habitat structures, floristics and food distribution (Gomes, 2002). The loss of frugivores may have consequences in forest regeneration since

many tropical forests produce large, lipid-rich fruits adapted for animal dispersal (Wright et al., 2007).

1.4.3 Seasonal variation

Habitat alteration is not only affecting biodiversity but also changes in forest ecosystem and its function (Mohamed Zakaria, 2002, Mohamed Zakaria, 2005). Degraded ecosystems are less resistant to climate change than healthy ecosystems. The changes will have major impacts on specialized or forest interior species which likely to disappear or shifted to another habitat. Earth's surface temperature has increased about 0.6°C during the past century and it is projected to increase about 2-6°C by 2100 (Zwiers, 2002). The changes of global climate had become one of the most important factors in altering distribution and abundance of biotas across the earth (Warren et al., 2001).

Bird species may be affected by climatic changes through alterations in species densities of specific locations, shifted of habitat range involving elevation, and behavioral changes such as phenology of migration and breeding (Root et al., 2003, Gordo, 2007, Peh, 2007). Consequences of climate change are more apparent in drier forests than tropical forest. Malaysia experienced an equatorial climate of constantly high day temperatures (average 28-30°C) and rainfall throughout the year (average 2000-3000mm of annual rainfall), and does not suffer prolonged drought. However, the consequences of global climate change should not be neglected as it affected the tropical resident and migratory birds (Sodhi, 2007).

Migratory species are an ideal indicator for broad-scale environmental assessment (Tankersley, 2004). High mobility allows migratory species to respond quickly to habitat destructions. Shifting in their migratory pathways and stopover sites may highlights crucial

habitats which started to decline (Tankersley, 2004). Furthermore, the migrants that exhibit specific migratory routes may also decline in numbers due to habitat alteration that occurs in specific stopover sites. Habitat alteration may change geographical landmarks which had been used for migrants in navigating its migratory routes. The timing of arrival and departure might be affected by extreme changes of temperature of origin or stopover habitat (Sodhi, 2007). Insectivores species such as flycatchers (Muscicapidae) and warblers (Sylviidae) breed in temperate Asia. They migrate to tropical zones when insects are limited in temperate zones with the onset of winter.

Migrants arrived in Peninsular Malaysia and Singapore in September to November when food supplies in north region are limited (Strange, 1993). In addition to arrival of migrants from temperate zones, few tropical species also migrate southward. Migrations within the tropics are stimulated by the start and finish of rainy seasons but the ultimate cause of migration is the same as in higher latitudes, i.e food supply (Strange, 1993). Altitudinal migration among resident frugivorous birds in lowland rainforest occurred in corresponded with local fruit supply (Kimura, 2003). Habitat alteration may also decline the quality of stopover sites thus not able to fulfill the requirements needed by migrant species (Kimura, 2003). Therefore, the presence of migrant species in a habitat may aid in improving habitat management in order to conserve the diversity of avifauna in a specific habitat.

1.5 Importance of diversity assessment

Forest loss due to urbanization and logging activities has become a serious problem throughout tropical rainforest especially Southeast Asia (Owiunji and Plumptre, 1998, Sodhi, 2004). This phenomenon is detrimental to birds diversity since it will reduce quality and quantity of undisturbed habitat (Sodhi, 2004). Therefore, study on birds diversity in affected areas is crucial in gathering information on how serious this phenomenon had affected community structure. Ability of forest birds to become environmental indicator of forest health can be useful in determining disturbance level of specific habitat (Peh, 2005). Role of Virgin Jungle Reserve (VJR) in any areas is important to support the persistence of forest dependent species especially when it is located nearby disturbed habitat. If logged forest was left untouched it will regenerates to harbor and conserve more important species. Although this study was conducted in a short period, the findings may give an idea on community structure and will help in forest management practice for conservation purposes. Long-term studies are needed to assess overall community structure covering forested area.

1.6 Research objectives:

i. To study the understorey bird assemblages in two lowland forests
ii. To classify the bird status, abundance status and conservation status of all captured birds
iii. To study the relationships between rainfall and migratory season affecting assemblages of understorey birds
iv. To contrast bird assemblages between logged forest and virgin jungle reserv

CHAPTER 2: METHODOLOGY

2.1 Study sites

The study was conducted from January 2009 to December 2010 in two selected forest reserves in Peninsular Malaysia. The study was focused on lowland dipterocarp forest that has two different forest habitats; Virgin Jungle Reserves (VJR) consist of primary forest and forest compartment that had been logged (LF) at least six years ago.

2.1.1 Ulu Gombak Forest Reserve, Selangor (UGFR)

Ulu Gombak Forest Reserve (UGFR) is located 30 kilometers from Kuala Lumpur on the north side of Kuala Lumpur-Bentong road (N 03°19.111';E 101°45.912'). The forest consists of different forest habitat ranging from lowland dipterocarp to montane forest. The topography is rough, with steep hillside and narrow valley bottoms. It have an altitude ranging from 100-800m. The valley was cut by numerous small streams that flow within it. The size of the forest reserve is approximately 17,000 hectares. Of this, 499 hectares are Virgin Jungle Reserve (VJR). It had been logged approximately 50 years before and had been gazette as forest reserve.

The mean temperature recorded in 2009 and 2010 was between 26-27ºC. The relative humidity (83-85%) was high and the mean rainfall is between 223-227 mm (Malaysian Meteorological Department, 2010). Various types of timber species can be found in the forest reserve. The most common and dominant species is seraya (*Shorea curtisii*) followed by meranti (*Shorea* sp.), mersawa (*Anisoptera* sp.), keruing (*Dipterocarpus* sp.), keranji (*Dialum patens*) and others. The remaining typical lowland species include various types of meranti species such as meranti tembaga (*Shorea leprosula*), meranti kepong (*Shorea ovalis*), and meranti sarang punai (*Shorea parvifolia*);

merbau (*Instia palembanica*), kerdas (*Pithecellobium bubalinum*), and kempas (*Kompassia malaccencis*). Secondary vegetation such as mahang (*Macaranga* sp.), terap (*Artocarpus rigidifolius*), temponek (*Artocarpus scortechinii*), balek angin (*Mallotus paniculatus*) and bamboos (*Gigantochloa scortechinii*) were also recorded. There are numerous species of leguminous (*Saracca* sp.) growing at the edge of the stream. The most common species is *Saracca thaipingensis* that has bright yellow cauliflorous/ramiflorous flowers and purplish brown large flattened pods. Medium sized trees such as kasai (*Pometia pinnata*), kelat and jambu (*Eugenia* sp.), and several species of figs (*Ficus* sp.) also can be found along the stream.

The reserve was surrounded by development area because it is located adjacent to the Karak Highway, one of the country's major highway heading to eastern part of Peninsular Malaysia. Human settlements are also located close to the reserve. The forest reserve was declared as educational forest in 1980s and a lot of nature education programs have been conducted within the forest reserve. The forest was listed as one of the most popular bird watching spot (Bransbury, 1993) and Important Bird Areas (BirdLife, 2012). Since some of the forest compartments were separated by major highway or federal road, there is an increasing usage of forest boundaries as transportation route and also for recreational activities such as cycling and jogging.

2.1.2 Triang Forest Reserve, Negeri Sembilan (TFR)

Triang Forest Reserve (TFR) is located about seven kilometers from Kuala Klawang, in Jelebu, Negeri Sembilan (N 02°55.631';E 102°07.814'). The size of the forest reserve is about 50,000 hectares. The forest has been gazette as Forest Reserve in 1909. The forest consists of logged and unlogged compartments where unlogged forest (Compartment 87) is about 227.8 but 9.7 hectares had been utilized to build road in 1987. The unlogged forest was separated from logged forest by a river and logging track. Another piece of unlogged forest was located in Compartment 82, approximately 142.8 hectares where most of the forest (122.12 hectares) have been logged in 2005 and the remaining 20.68 hectares remain untouched.

The temperature average was between 26-27ºC, with 79% of mean relative humidity and mean rainfall between 123-130mm in 2009 and 2010 (Malaysian Meteorological Department, 2010). Few timber species such as meranti (*Shorea* sp.), mersawa (*Anisptera* sp.) and keruing (*Dipterocarpus* sp.) were survived in the forest reserve. In addition, typical lowland species such as kedondong (*Canarium littorale*), kempas (*Kompassia malaccencis*), terap (*Artocarpus rigidifolius*), several species of figs (*Ficus* sp.) and many more can also be found. Along the logging track and forest edge, there are abundance of succession species such as wild banana (*Musa* sp.) and ginger (*Zingiber* sp.). The forest reserve was surrounded by rubber plantation (*Hevea brasiliensis*) and human settlement. Indigenous people utilized the forest resources such as rattan and bamboos. The forest was also used by Malaysian army as their training field.

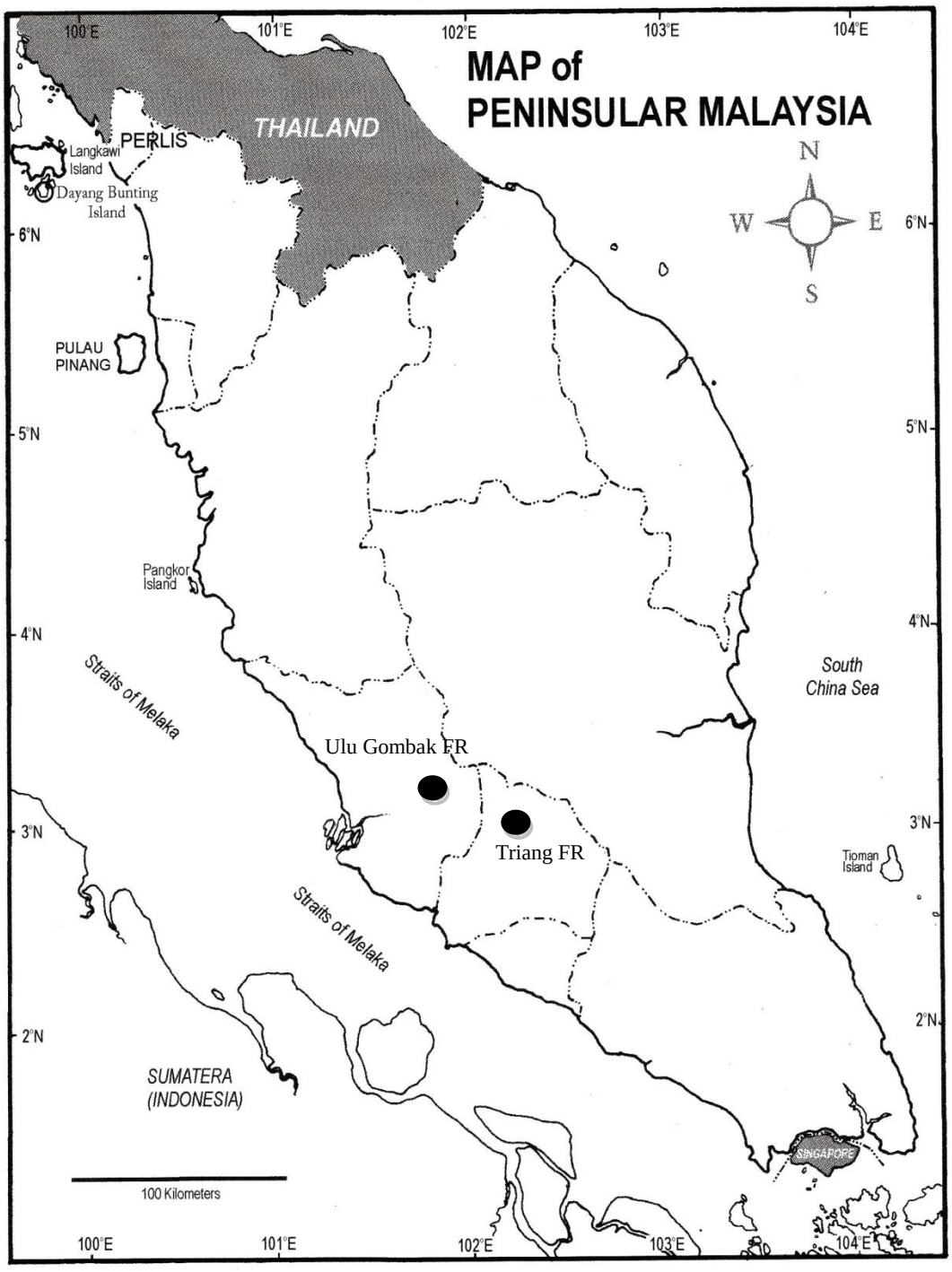

Figure 2.1: Location of study sites

2.2 Sampling design

2.2.1 Mist-netting method

Mist-netting method was used to gather information on diversity of understorey birds in lowland rainforest. This method is widely used in tropical forest because it involves random sampling and does not rely on assumption like territoriality (Zamri, 2002). This is a passive method in capturing understorey birds as compared to aural or observational method. The differences between both techniques is that mist nets captured bird by chance while point counting requires skilled observers to detect birds by sound or sight (Whitman et al., 1997). However, mist-netting is very effective in capturing inconspicuous and secretive understorey birds (Zamri, 2002). The method is commonly used as a valuable tool for monitoring bird population in a specific habitat (Dunn, 2004).

Since the birds that were trapped by this method are by chance, it is very important to select suitable site to set up the nets. Suitable site include habitat that has potential food resources, streams and places that can reduce net visibility to the birds. Twenty mist nets measuring 12m x 2.5m with mesh size of 36mm² were set up randomly within selected habitat. The nets were erected along available forest trail that had been used as line transect. The distance between one net to another is about 30 meters and all nets were set up at approximately 0.5 meter above ground level. Mist netting was carried out for a total of 144 days on both study sites; 72 days in UGFR, 72 days in TFR.

Most understorey birds are active during morning (while searching for food) and also in the afternoon (while heading towards their roosting sites). Therefore, all nets were operated from 0700 hours until 1800 hours. All nets were operated for 11 hours a day for three consecutive days during each visit except during heavy rain or strong wind. Three days of netting are sufficient in capturing most understorey birds in the area. Birds may detect the present or remember the location of mist nets after the third day and therefore reduce success rate. The nets were closed during heavy rain or windy day, subsequently opened whenever the conditions improved. This is to reduce risk of bird mortality and preventing damage to nets by falling branches. The nets were checked hourly to ensure immediate extraction of captured individuals, avoiding mortality and risks of being attacked by predators.

Captured birds were temporarily held in cloth bags before morphological measurements were carried out. All birds were morphologically measured, weighed, sexed and checked for molting. The birds were identified up to species level and field guides such as Jeyarasingam and Pearson (1999) and Robson (2005) were used. All birds except kingfishers were then banded with aluminium ring. This ring bear serial number to allow identification and avoid multiple counting in case of recapture. The birds were released at point of capture to reduce disruption on their daily activity.

2.2.2 Morphological measurements

The measurements that were taken for each captured bird followed criteria proposed by McCracken (1999) which included body weight, body length, tail length, wing length, tarsus length, culmen and gape, height and width of the bill and, keel. All measurements were in millimeters (mm) and body weight (in gram). These measurements were useful in species identification and sex determination. In addition, body weight also can be used as a good indicator of bird's health especially while they are migrating, breeding, moulting or loafing.

2.2.3 Ringing method

All captured birds, except kingfishers, were ringed by aluminium ring that bear serial numbers. Birds were marked to avoid multiple counting. Ring size was measured by its internal diameter. Suitable ring size is dependent on bird's leg radius. The ring should be well fitted to the bird's leg to avoid injury or affecting movements. Ringing is an efficient way to gather information about breeding and migratory routes of migratory birds. It also provides information on the survival and mobility of resident population (Jeyarasingam, 1998).

2.3 Feeding guild

During species identification, the bird was classified into different feeding guild based on their referred diets. Guilds are assemblages of species utilizing particular resources in a similar manner (Owiunji and Plumptre, 1998). The analysis of guilds will provide information on how other guild members respond towards habitat changes in particular habitat (Owiunji and Plumptre, 1998). The feeding guild was divided into six major groups, i.e. Carnivorous (CR), Insectivorous (IN), Frugivorous (FR), Nectarivorous (NEC), Omnivorous (OM) and Granivorous (GR). Omnivorous are generalist species that has more than one feeding guild such as frugivorous/insectivorous (FR/IN), nectarivorous/insectivorous (NEC/IN), frugivorous/nectarivorous (FR/NEC), and frugivorous/nectarivorous/insectivorous (FR/NEC/IN).

2.4 Rainfall data

Malaysia experienced biannual monsoon seasons, receiving heavy rains from November to March while lighter rain in May to September (Malaysian Meteorological Services, 2009 and 2010). Annual mean rainfall data from the nearest meteorological station for each site were obtained from the Malaysian Meteorological Department. The nearest meteorological station for Ulu Gombak Forest Reserve was located at Ulu Klang, approximately 22 kilometers from the reserve. The nearest meteorological station for Triang Forest Reserve was located at Hospital Jelebu, Negeri Sembilan, approximately 12 kilometers from the reserve.

2.5 Bird status

The status of captured birds was determined during identification process following classifications by Wells (2007) and MNS (2005 and 2010). The classification status were as followed:

2.5.1 Resident (R)

Resident species is known to breed within Peninsular Malaysia's political boundaries. This include exotic species which have established breeding population in Peninsular Malaysia.

2.5.2 Migrant (M)

Migratory birds are using Peninsular Malaysia territory during northern or southern winter seasons. This include local migrant which are defined as population of resident species that are subject to local movement during breeding and non-breeding periods. Migratory season of Malaysia occurred in September to May (Strange, 1993)

2.5.3 Vagrant (V)

Vagrants are migratory species which end up in areas outside their normal wintering range. Initially a species which is naturally expanding its range into Peninsular Malaysia will be listed as vagrants but over time, the status will be upgraded to migrant visitor based on their regular usage of Peninsular Malaysia territory as part of their natural migratory range.

2.5.4 Extirpated (X)

A species with no record in the wild of Peninsular Malaysia territory within the last 50 years were listed as extirpated.

2.5.5 Irregular (I)

A species which recorded less than anually

2.6 Status of abundance

The abundances and occurrences status of captured birds were determined following classification provided by Jeyarasingam and Strange (1993), Wells (2007) and MNS (2005; 2010). The abundance assessment is subjective and not empirical. This was based on a consensus opinion among experience birders of different parts of Peninsular Malaysia. However, in this study, the frequency of species occurrence was added into the abundance assessment to support the classification status.

2.6.1 Rare and localized

Rare species can be found in one or two sites where there is a slim chance of recording it. In this study, species that have cumulative frequency of less than ten individuals was classified as rare species.

2.6.2 Uncommon and localized

A species is considered uncommon when it was found in sites where there is a chance of recording it. Species which was represented by 10-19 individuals was classified as uncommon.

2.6.3 Common and widespread

A species is common when it was found in a wide variety of habitats. The common species was represented by between 20 to 49 individuals.

2.6.4 Abundant and widespread

Abundant species can be easily seen or heard in variety of habitats. The species was represented by more than 50 individuals in each study sites.

2.7 Global conservation status

The conservation status of captured birds was determined following global listing of threatened species of IUCN Red List. The categories of threat are described following the criteria developed by the IUCN. The classification are as followed:

2.7.1 Extinct (EX)

A taxon is considered as Extinct when there is no reasonable doubt that the last individual was died. The taxon was also considered Extinct when exhaustive survey in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record any individual. Survey should be conducted over a time frame appropriate to the taxon's life cycle and life form.

2.7.2 Extinct in the Wild (EW)

A taxon which is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range are considered as Extinct in the Wild. A taxon is presumed Extinct in the Wild when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record any individual. Surveys should be conducted over a time frame appropriate to the taxon's life cycle and life form.

2.7.3 Critically Endangered (EN)

Critically Endangered taxon is when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered, therefore it is considered to be facing an extremely high risk of extinction in the wild.

2.7.4 Endangered (EN)

Endangered is when the best available evidence of a taxon indicates that it meets any of the criteria A to E for Endangered. The taxon are considered to be facing a very high risk of extinction in the wild.

2.7.5 Vulnerable (VU)

Vulnerable is when the best available evidence of a taxon indicates that it meets any of the criteria A to E for Vulnerable, therefore it is considered to be facing a high risk of extinction in the wild.

2.7.6 Near Threatened (NT)

Near Threatened is when a taxon has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but it is close or likely to qualify for a threatened category in the near future.

2.7.7 Least Concern (LC)

Least Concern is when a taxon has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.

2.8 Data analysis

2.8.1 Classification of species

Several terms were used to categorize captured species into several groups based on their abundance and distribution. Generalist species was defined as species that were captured in both study sites or habitats while specialist species was species that were captured only in one study site or habitat. Singleton species was represented by only a single individual.

2.8.2 Capture rate

Capture rate was calculated to reduced biases in sampling and to presents more accurate data for each study site. Capture rate indicates successful sampling effort of each study site which were shown by species ratio based on number of netting hours. Capture rate was calculated using following formula:

$$\text{Capture rate} = \frac{\text{Number of individuals captured}}{\text{Number of netting hours}}$$

Netting hours was calculated using this formula:

$$\text{Netting hours} = A \times B \times C$$

where A=total mist nets in each sampling (i.e 20 mist nets), B=total number of sampling hours (between one to 11 hours per day), C=number of sampling days (i.e three days)

2.8.3 Diversity analysis

Diversity of a community refer to species richness, abundance or a combination of all these (He et al., 1996). Richness is number of species in a specific site whilst abundance is total number of individual of all species found (He et al., 1996). To compare total number of individuals and species recorded from study areas, various indices such as Berger-Parker Index of dominance, Shannon-Weiner Index (H), Simpson's Index (D), and Simpson's Evenness Index (E) were used. Berger-Parker Index of Dominance was used to express the proportional importance of the most abundance or dominance species and was considered by May (1975) as one of the most satisfactory diversity measures.

Shannon-Weiner and Simpson's are indices that considered species richness and abundances and both are useful in diversity studies. Shannon-Weiner index is the most well-known and widely used (He et al., 1996) while Simpson's Index reflects the degree of dominance in the most common species in the community. Both indices take into account species richness and abundance therefore both are useful in diversity studies. A site that has greater evenness is usually considered more diverse than a site with few dominant dominate, even though the alpha value may be higher in the site showing greater dominance.

Species accumulation curve had been plotted for both habitats in both study sites to illustrate the completeness of sampling efficiency. The non-asymptote curve showed that not all species in each sampling site have been captured during sampling. Therefore, estimation of total species richness was calculated using First-order Jackknife to estimate projected species richness at increasing level of sampling effort. Estimation of maximum species that can be found in certain habitat is useful to obtained further information on

whether continued sampling justifies the cost. For diversity analysis, Species Diversity and Richness Program Version 4 was used (Seaby and Henderson, 2006). Index of similarity was calculated using Sorensen Index or Sorensen Similarity Coefficient to measure the degree of similarity when comparing the species assemblages of two habitats or two study sites. The index focused on common species recorded in all sites and particular species that was found only in one site.

2.8.4 Statistical analysis

Significant difference between two means (average) from two sets of data was determined using Mann-Whitney test. The test was used to test small data size where it has the possibility of significantly differ from normal distribution. Chi-square test is used to determine if there is an association between two variables measured at nominal scale. It is used for non-parametric data which does not require rigid requirements as in parametric method.

Correlation determine the relationship between two variables measured in interval or numerical scale. A strong and positive relationship shows increase values of first variable will be followed by an increase value of second variable. Spearman correlation analysis was used to investigate the relationship between environmental parameter such as rainfall with the abundance of avifauna in different habitat and study site. All statistical analysis were done using SPSS version 19 software. P-values less than 0.05 ($p<0.05$) showed significant differences and $p>0.05$ showed non-significant differences.

CHAPTER 3: RESULTS

3.1 Understorey birds assemblages in UGFR and TFR

A total of 2,370 individuals belonging to 120 species and 30 families were captured in both study sites. More species was recorded in TFR with 1,638 individuals that belonged to 96 species and 27 families. Ulu Gombak Forest Reserve recorded 732 individuals belong to 82 species and 24 families (Figure 3.1-1). There is no significant different in species abundance between study sites (Mann-Whitney U test, p=0.542). Diversity values showed that UGFR is more diverse than TFR although the former area has lower capture rate (Shannon-Weiner index: 3.751, Simpson D index: 29.89). UGFR also recorded a more even bird community (0.3645) compared to TFR (0.0746) (Table 3.1-1).

Species accumulation curves postulated that more birds should be captured in study areas (Figure 3.1-2). Newly recorded species was still being added into the list during next sampling at both study sites. The newly added species showed rapid increased during early sampling but slowing down towards the end of sampling periods. The curve had not reached an asymptote yet indicating that not all species presence in both study sites was sampled. However, First-order Jackknife estimated that understorey birds species were well sampled in UGFR. On contrary, not all species were sampled in TFR since it has low estimated species richness (Table 3.1-2).

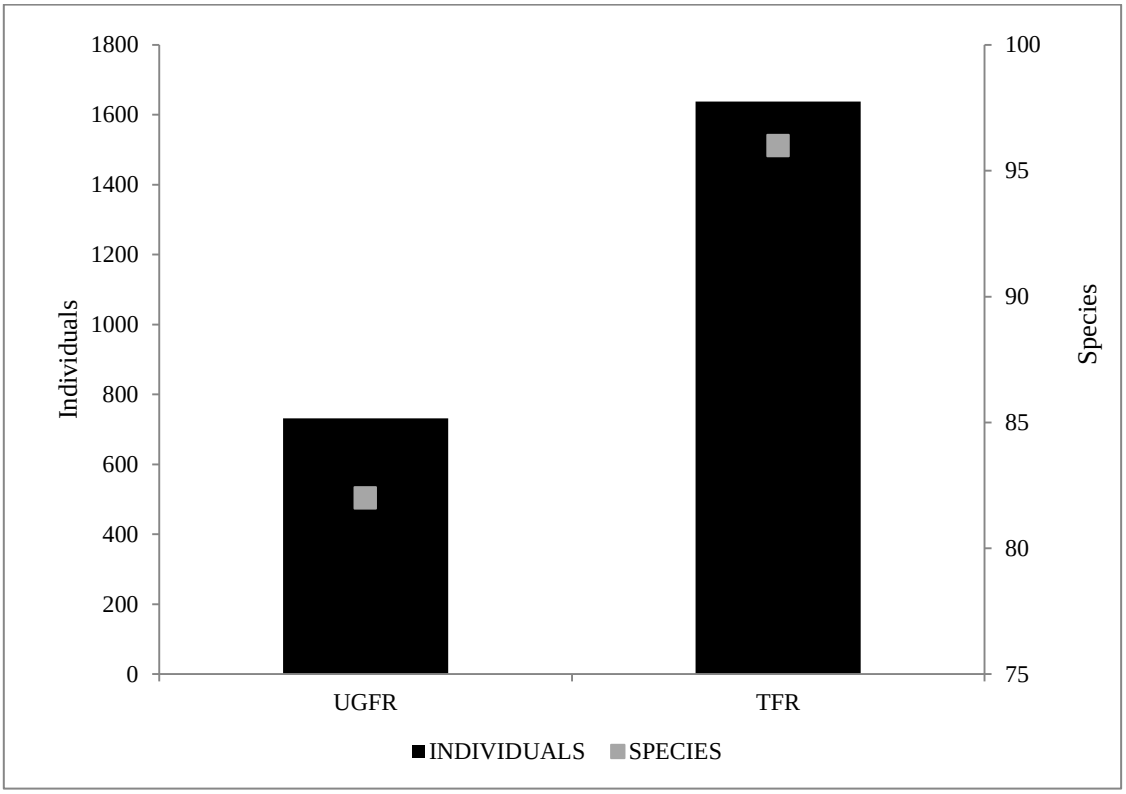

Figure 3.1-1: Total number of individual and species captured recorded in UGFR and TFR

Table 3.1-1: Diversity values of understorey birds in UGFR and TFR

Indices	UGFR	TFR
Berger-Parker Dominance (D_{BP})	0.0861	0.3584
Shannon-Weiner (H')	3.751	3.144
Simpson's Index (D)	0.965	0.859
Simpson Evenness (E)	0.3645	0.07462

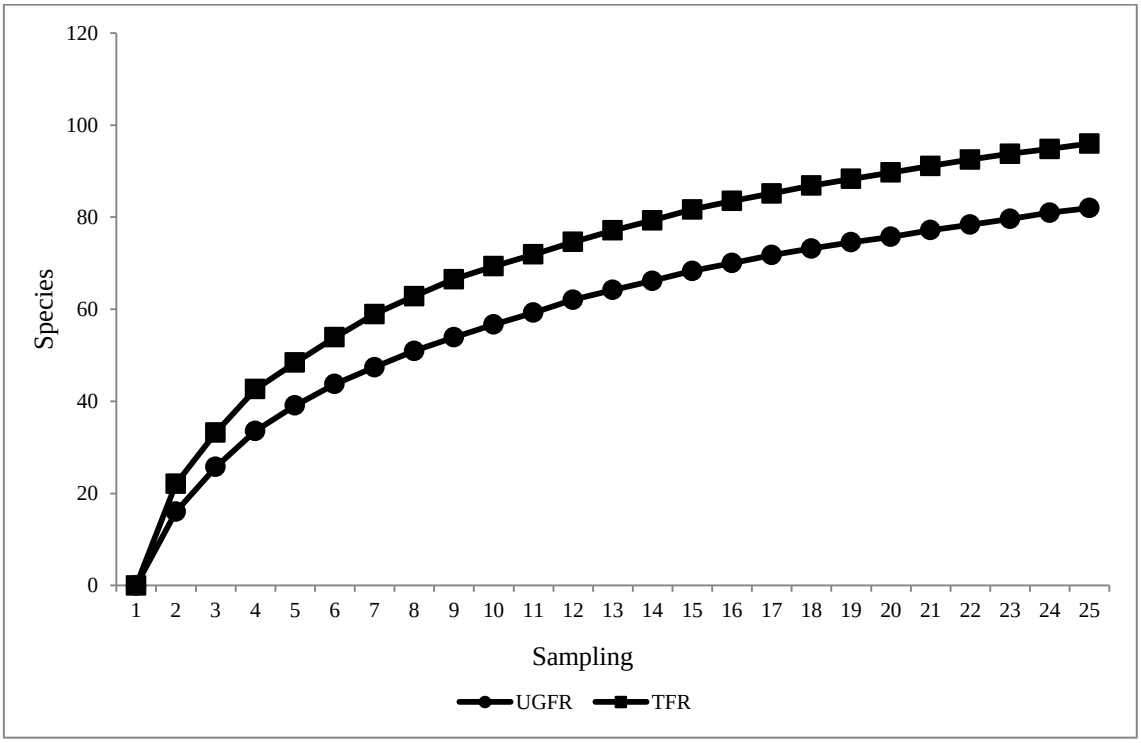

Figure 3.1-2: Species accumulation curve for understorey birds of UGFR and TFR

Table 3.1-2: First-order Jackknife estimator for understorey birds of both study sites

Study sites	Number of recorded species	First-order Jackknife	SD	% of estimated species richness
UGFR	82	82	0	100%
TFR	96	151	7	63.5%

3.1.1 Species composition

3.1.1 (a) Highest species representatives

Family Timaliidae has highest species representative with 20 species. From this, 16 species were captured in TFR and 12 species were sampled in UGFR. Family Muscicapidae was represented by 18 species where 13 species were captured in TFR and 15 species were recorded in UGFR. Family Pycnonotidae was represented by 15 species where 12 species were captured in TFR and 13 species were captured in UGFR.

3.1.1 (b) Highest individual representatives

Members of family Nectariniidae were recorded highest individuals captured with 729 birds represented by nine species, 90% of the family was recorded in TFR. Little Spiderhunter (*Arachnothera longirostra*) was the most abundant species with 623 individuals followed by Purple-naped sunbird (*Hypogramma hypogrammicum*) with 64 individuals. Family Timaliidae was represented by 382 individuals that can be classified into 20 species, 70% (252 individuals) of this family member was captured in TFR and only 30% (130 individuals) were recorded in UGFR. This family was mostly represented by two species i.e Grey-throated Babbler (*Stachyris nigriceps*) and Chestnut-winged Babbler (*Stachyris erthroptera*). Both species are common in both study sites. The former species was represented by 85 individuals while the latter species was represented by 48 individuals.

3.1.2 Species similarity between UGFR and TFR

There are 58 similar species of 19 families represented by 2,215 individuals were captured in both study sites (Sorensen similarity coefficient: 65%). Most of the individuals (1,545 birds) were recorded in TFR while the remaining was recorded in UGFR (Mann-Whitney U test, df=1, p=0.04). Of these, family Pycnonotidae has the highest represented species with ten species contributed by 352 individuals, followed by family Muscicapidae also by ten species (represented by 236 individuals), and family Timaliidae with eight species (consist of 340 individuals).

Of 58 species, there were nine species showed significant difference in terms of species abundance (Table 3.1-3). Among these, Little Spiderhunter (*Arachnothera longirostra*) of family Nectariniidae was the most abundant species and 94% of this species was captured in TFR (χ^2=167.06, df=1, p<0.05). Species such as Grey-throated Babbler (*Stachyris nigriceps*) (χ^2=84.92, df=1, p<0.05), Chestnut-naped Forktail (*Enicurus ruficapillus*) (χ^2=26.4, df=1, p<0.05) and Black-headed Bulbul (*Pycnonotus atriceps*) (χ^2=20.77, df=1, p<0.05) have bigger differences in species abundance and were captured more in UGFR.

Table 3.1-3: List of similar understorey birds species which has significant difference (p-value=$p<0.05$) in species abundance between Ulu Gombak Forest Reserve (UGFR) and Triang Forest Reserve (TFR) using Chi-square test (χ^2).

COMMON NAME	**UGFR**	**TFR**	χ^2
Black-headed Bulbul	15	5	20.77
Chestnut-naped Forktail	30	18	26.40
Grey-eyed Bulbul	10	5	10.02
Grey-throated Babbler	63	22	84.92
Hairy-backed Bulbul	35	43	9.59
Little Spiderhunter	36	587	167.07
Orange-bellied Flowerpecker	18	13	12.83
Rufous-backed Kingfisher	61	66	22.47
Spectacled Bulbul	23	25	8.39

3.1.3 Specialist species of UGFR and TFR

Twenty four species which were represented by 62 individuals were recorded only in UGFR. This group was dominated by Yellow-bellied Warbler (*Abroscopus superciliaris*) with 12 individuals. Family Timaliidae has the highest representatives with 15 individuals that belong to four species and Pin-striped tit Babbler (*Macronus gularis*) formed biggest representatives with 10 individuals. Family Muscicapidae was represented by nine individuals of five species which was dominated by Tickell's blue Flycatcher (*Cyornis tickelliae*) and Verditer flycatcher (*Eumyias thalassinus*) with three individuals each. Three Near-threatened species i.e Red-throated Sunbird (*Anthreptes rhodolema*), Scaly-breasted Bulbul (*Pycnonotus squamatus*) and Diard's Trogon (*Harpactes diardii*) were represented by single individual while the remaining species were listed as Least Concern.

Thirty-eight species represented by 93 individuals were recorded in TFR only. Among these, Asian-paradise flycatcher (*Tersiphone paradisi*) has bigger representative with 14 birds. Similar to UGFR, members of family Timaliidae have more representatives with eight species (27 individuals) and Black-throated Babbler (*Stachyris nigricollis*) has the biggest representatives with nine individuals. Two Near-threatened species i.e Crested Jay (*Platylophus galericulatus*) and Cinnamon-rumped trogon (*Harpactes orrhophaeus*) and a Vulnerable species i.e Grey-chested jungle flycatcher (*Rhinomyias umbratilis*) were recorded in TFR while the remaining are Least Concern species. Near-threatened species i.e Lesser green Leafbird (*Chloropsis cyanopogon*), Dark-throated Oriole (*Oriolus xanthonotus*), Black-and-white Bulbul (*Pycnonotus melanoleucos*) and Red-throated Barbet (*Megalaima mystacophos*) were among 19 singleton species while the remaining are Least Concern.

3.1.4 Feeding guild composition

The feeding guild composition was not significantly different between study areas (Mann-Whitney U test, p=0.293). Overall, insectivorous birds dominated both study areas (χ^2=14.026, df=1, p<0.05), followed by frugivorous/insectivorous birds (χ^2=30.475, df=1, p<0.05) (Table 3.1-4). However, nectarivorous/insectivorous birds are dominant group in TFR compared to UGFR with 656 individuals that belong to four species (χ^2=189.061, df=1, p<0.05) (Table 3.1-4) (Figure 3.1-3).

3.1.4.1 Highest species and individual representatives in UGFR

Insectivorous birds were dominated by family Muscicapidae and Timaliidae. These families consist of 108 individuals of 15 species (37%) and 66 individuals of 11 species (23%) respectively. Of this, White-rumped Shama (*Copsychus malabaricus*) and Chestnut-naped Forktail (*Enicurus ruficapillus*) were the most abundant species of Muscicapidae with 12 individuals (21%). Members of family Timaliidae were dominated by Moustached Babbler (*Malacopteron magnirostre*) and Grey-headed Babbler (*Stachyris poliocephala*) with 10 and 17 individuals each.

Table 3.1-4: Feeding guild composition of understorey birds (p-value= $p<0.05$) inhabiting Ulu Gombak Forest Reserve (UGFR) and Triang Forest Reserve (TFR) (χ^2=chi-square value).

FEEDING GUILDS	UGFR	TFR	χ^2
CR	84	120	12.183
IN	292	519	14.026
FR	64	84	12.403
FR/IN	181	248	30.475
NEC/IN	43	656	189.061
FR/NEC	35	42	8.784
FR/NEC/IN	36	48	6.636

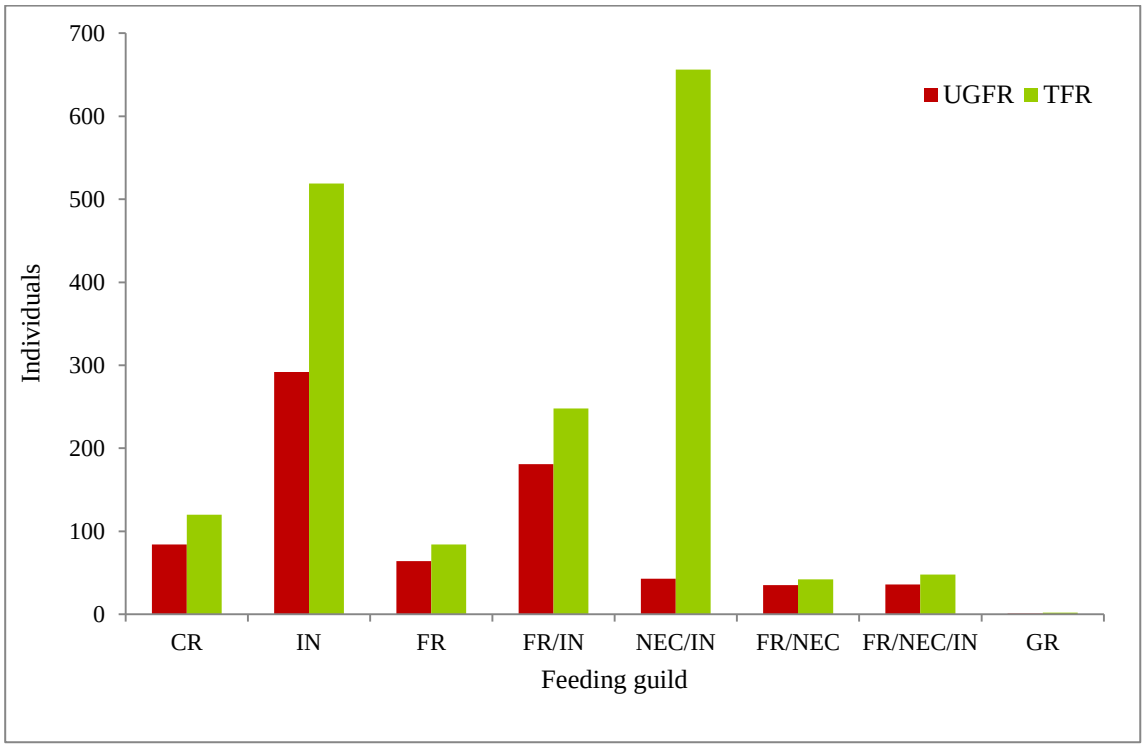

Figure 3.1-3: Feeding guild composition of avifauna in UGFR and TFR

Frugivorous/insectivorous (FR/IN) birds were heavily represented by family Pycnonotidae with 100 individuals (55%) that belong to eight species. Within this group, Hairy-backed Bulbul (*Tricholestes criniger*) and Spectacled Bulbul (*Pycnonotus erythropthalmos*) were the most dominant with 35 individuals (81%) and 24 individuals (42%) respectively. Grey-throated Babbler (*Stachyris nigriceps*) of family Timaliidae also recorded highest individual representative of frugivorous/insectivorous birds with 63 individuals (35%). Carnivorous birds were frequently represented by family Alcenididae with 83 birds (11%) that belong to five species. Rufous-backed Kingfisher (*Ceyx rufidorsa*) was the most common species captured with 61 individuals (73%).

3.1.4.2 Highest species and individual representatives in TFR

Nectarivorous/insectivorous (NEC/IN) birds were dominated by family Nectariniidae that was represented by 656 individuals of four species. Of these, Little Spiderhunter (*Arachnothera longirostra*) was the common species with 634 representatives.

Insectivorous (IN) birds were usually represented by family Timaliidae and Muscicapidae with 232 individuals (45%) of 15 species and 30% or 154 individuals (30%) of 11 species respectively. Scaly-crowned Babbler (*Malacopteron cinereum*) and Chestnut-winged Babbler (*Stachyris erythropthera*) were the most common species of family Timaliidae with 49 individuals (9%) and 46 individuals (9%) respectively while family Muscicapidae were dominated by White-rumped Shama (*Copsychus malabaricus*) with 48 individuals (9%) and Chestnut-naped Forktail (*Enicurus ruficapillus*) with 25 individuals (5%).

Frugivorous/insectivorous birds were dominated by family Pycnonotidae with 162 individuals (65%) that belong to eight species. Yellow-bellied Bulbul (*Alophoixus phaeocephalus*) and Hairy-backed Bulbul (*Tricholestes criniger*) recorded highest individuals captured with 60 individuals (26%) and 44 individuals (19%) respectively. Near-threatened species such as Green Broadbill (family Eurylaimidae) was represented by 24 individuals (10%) in TFR.

3.2 Monthly Distribution of Understorey birds

3.2.1 Ulu Gombak Forest Reserve (UGFR)

A total of 736 individuals of 82 species and 24 families were captured in UGFR for two consecutive years. Of these, 385 birds belong to 64 species and 21 families were recorded in 2009. On contrary, only 351 birds that belong to 64 species and 20 families were captured in 2010. A Mann-Whitney test was conducted to evaluate differences of species abundance in both years, and the results showed non-significant differences (Mann-Whitney U test, df=1, p=0.885). Even though capture rate of 2009 was higher than 2010 (0.057 versus 0.047), diversity indices values showed that birds captured in 2010 was more diverse than 2009. The distribution of species in 2010 was more than 2009 (Table 3.2-1).

In 2009, the highest individual number and species were captured in July with 66 individuals (17%) that belong to 29 species (capture rate=0.114), followed by June with 58 individuals (15%) of 19 species (capture rate=0.104) (Figure 3.2-1). In 2010, highest number of species and individual were recorded in October which were represented by 48 individuals (14%) of 22 species (capture rate=0.077), followed by July with 42 individuals (12%) of 20 species (capture rate=0.069) (Figure 3.2-1).

Table 3.2-1: Values of diversity indices of UGFR's avifauna for 2009-2010

Indices	2009	2010
Berger-Parker Dominance (D_{BP})	0.1269	0.07123
Shannon-Weiner (H')	3.555	3.681
Simpson's Index (D)	0.954	0.966
Simpson Evenness	0.36	0.5007

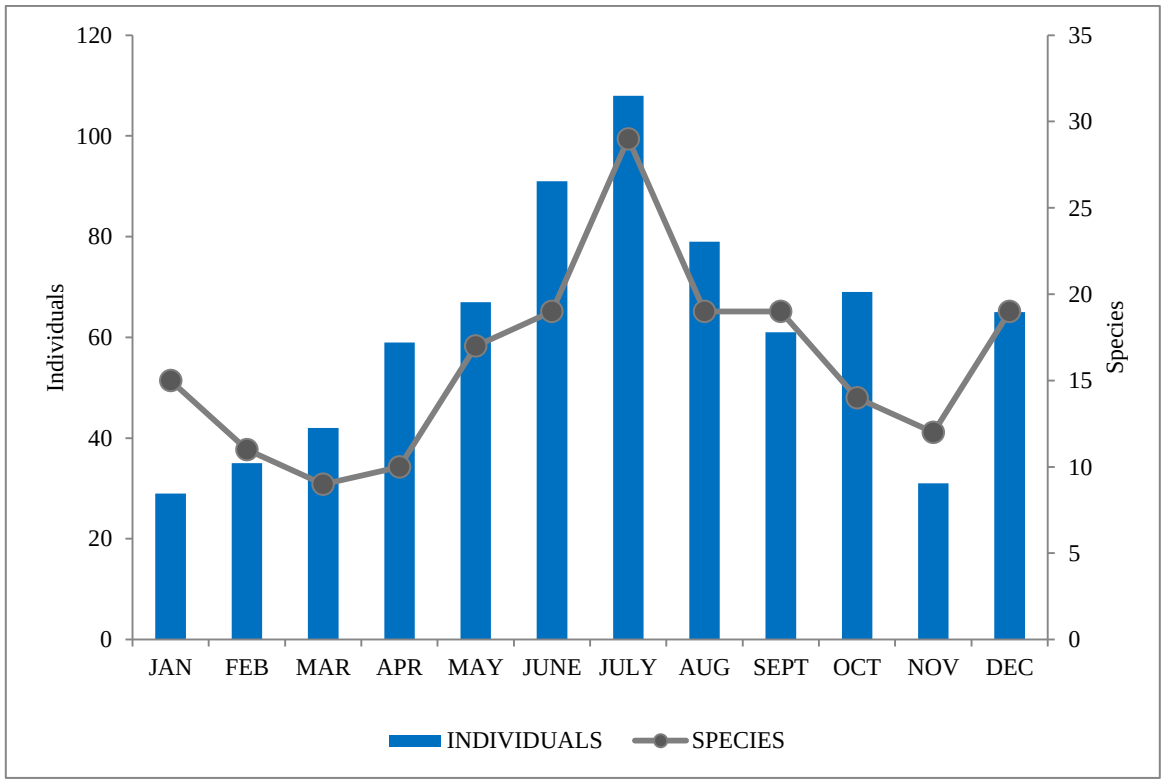

Figure 3.2-1: Monthly abundance of avifauna in UGFR

3.2.1.1 Community structure of understorey birds in UGFR

Family Muscicapidae was represented by the highest number of species (in 2009) with 13 species (20%) followed by family Pycnonotidae (in 2010) with 12 species (19%). However, Family Timaliidae has the highest individual representatives (in 2009) with 74 individuals (19%). Most captured bird is Grey-throated Babbler (*Stachyris nigriceps*) with 39 individuals (53%). In 2010, the highest individuals captured belong to family Pycnonotidae with 87 individuals (25%). Member of this family, Hairy-backed Bulbul (*Tricholestes criniger*) has the highest number of captured individuals 25 individuals (29%).

Overall, Grey-throated Babbler (*Stachyris nigriceps*) of family Timaliidae had most captured individuals in UGFR with 39 individuals (62%) recorded in 2009 and 24 individuals (38%) recorded in 2010. In 2009, this species was represented in nine sampling points and maximum capture was recorded in May with 12 individuals (31%). In 2010, this species only presence in six sampling points and the highest occurrence was recorded in October and December with 29% or seven individuals each.

Rufous-backed Kingfisher (*Ceyx rufidorsa*) of family Alcenididae also recorded highest individual captured where 49 individuals (80%) were captured in 2009 while the remaining 12 individuals (20%) were captured in 2010. This species was recorded in nine sampling points in 2009 where the highest captured was recorded in April with 12 individuals (24%). In 2010, this species was represented in six sampling points with the highest capture was recorded in May to July with three individuals (25%) each.

3.2.2 Triang Forest Reserve (TFR)

A total of 1,719 birds belong to 96 species and 27 families were captured in TFR during study period. Almost similar number of species and bird abundance was recorded in both years. However, the numbers are not significantly different (Mann-Whitney U test, df=1, p=0.977). A total of 859 birds belong to 76 species and 25 families were captured in 2009 while 861 birds belong to 79 species and 24 families were captured in 2010. Although bird's capture rate is higher in 2009 (0.133 versus 0.106), the diversity indices values suggested that birds population in 2010 is more diverse than 2009. In addition, bird's distribution is more even in 2010 than 2009 (Table 3.2-2).

In 2009, highest capture was recorded in September and this was contributed by 141 individuals (16%) which belong to 26 species. This was followed by August with 127 individuals (15%) of 24 species. In 2010, the highest individual and species capture rate were recorded in September which was contributed by 149 individuals (17%) of 30 species and second highest capture was recorded in July with 104 individuals (12%).

Table 3.2-2: Diversity indices value of understorey birds in TFR for 2009-2010.

Indices	2009	2010
Berger-Parker Dominance (D_{BP})	0.4529	0.2857
Shannon-Weiner (H')	2.76	3.271
Simpson's Index (D)	0.786	0.901
Simpson Evenness	0.06173	0.1292

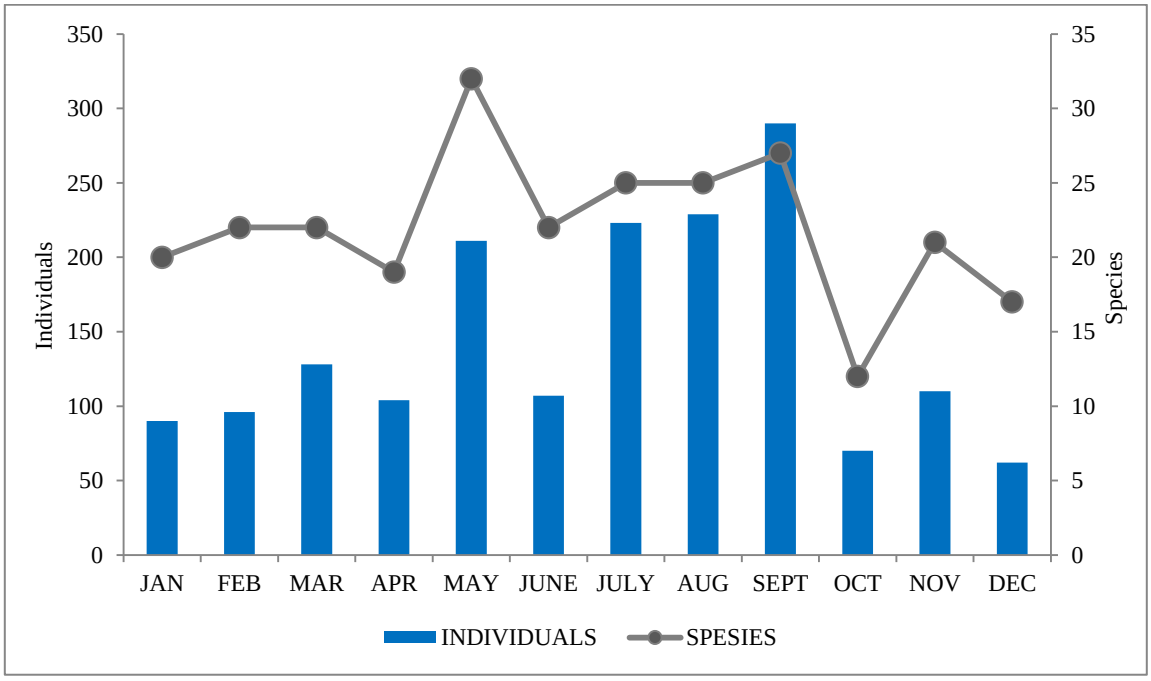

Figure 3.2-2: Monthly abundance of understorey birds in TFR

3.2.2.1 Community structure of understorey birds in TFR

Family Timaliidae was represented by the highest number of species in both years with 13 species recorded in 2009 and 15 species in 2010. Family Nectariniidae recorded the most abundant individuals represented by 435 birds (51%) in 2009 and 273 individuals (32%) in 2010. Little Spiderhunter (*Arachnothera longirostra*) is the most dominant species of the family with 37% or 634 individuals recorded in both years. There are 389 birds (45%) were captured in 2009 and it was highly recorded in July with 80 birds (67%). A total of 245 birds (28%) were captured in 2010 and highest capture was recorded in September with 86 individuals (58%). This species was recorded in all sampling points (Figure 3.2-5).

Individual of Rufous-backed Kingfisher (*Ceyx rufidorsa*) was highly recorded in both years (4% or 66 individuals). Sixteen birds (2%) were present in six sampling points in 2009 and the highest captured was recorded in April with 16% or eight individuals. In 2010, this species present in ten sampling points where 6% or 50 individuals were captured. It was captured mostly in May 2010 with 13% or 14 individuals (Figure 3.2-6).

3.3 Rainfall pattern

3.3.1 Rainfall and total birds in UGFR

UGFR accumulate 5395 mm of rainfall for a period of 2009 to 2010. The total rainfall in 2009 is 2675 mm which was contributed by 189 rainy days while; a total of 2720 mm rainfall was collected from 218 rainy days in 2010. Similar pattern of fluctuation in monthly rainfall was recorded in both years. The wet seasons were observed between March to May (average 348 -226mm) and September to November (average 320 - 331mm) while dry seasons were recorded from December to February (average 129-160mm) and from June to August (average 168-180mm).

Bird abundance pattern and capture rate were low during wet seasons. The lowest species abundance were recorded during higher rainfall in March (42 birds belong to nine species), capture rate (0.07 individual per hour) and November (31 birds of 12 species), capture rate (0.018 individual per hour) (Figure 3.3-1) (Figure 3.3-2). The minimum rainfall occurs in July when higher bird abundance (108 birds of 29 species) and capture rate (0.19 individual per hour) were recorded. However, analysis showed that bird abundance and capture rate was not significantly correlated with rainfall (species and rainfall: r= -0.542, p=0.07) (capture rate and rainfall: r=-0.51, p=0.089) in 2009 and (species and rainfall: r= -0.037, p=0.904) (capture rate and rainfall: r=-0.184, p=0.558) in 2010.

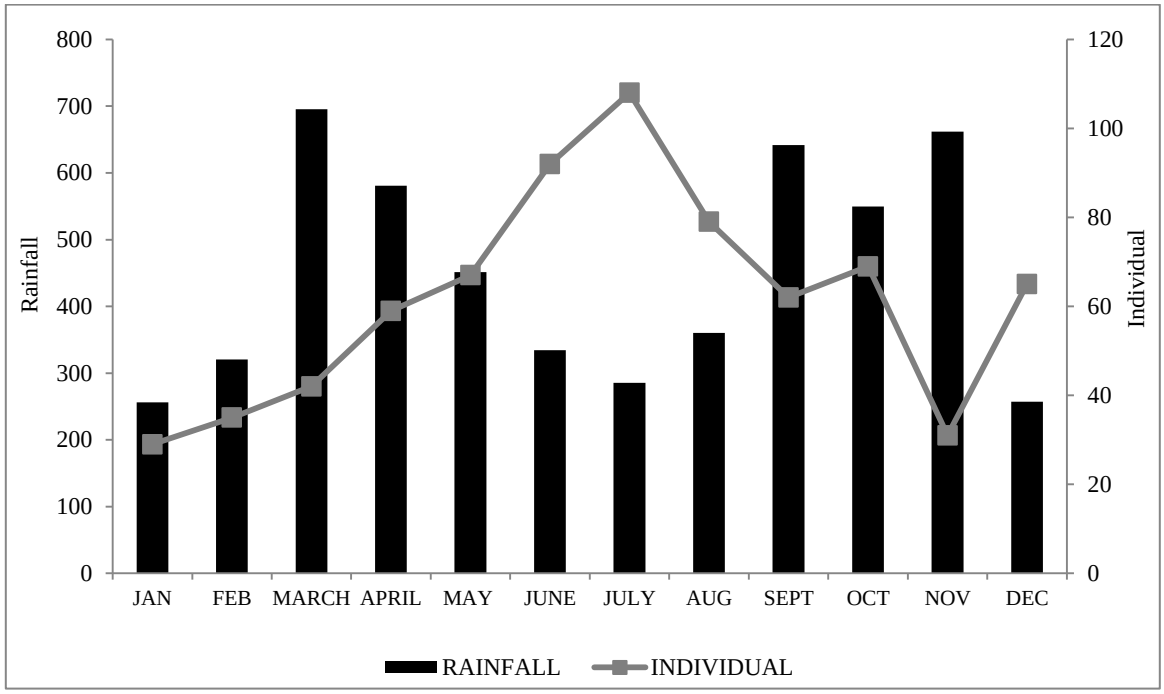

Figure 3.3-1: Monthly rainfall and total individuals in UGFR

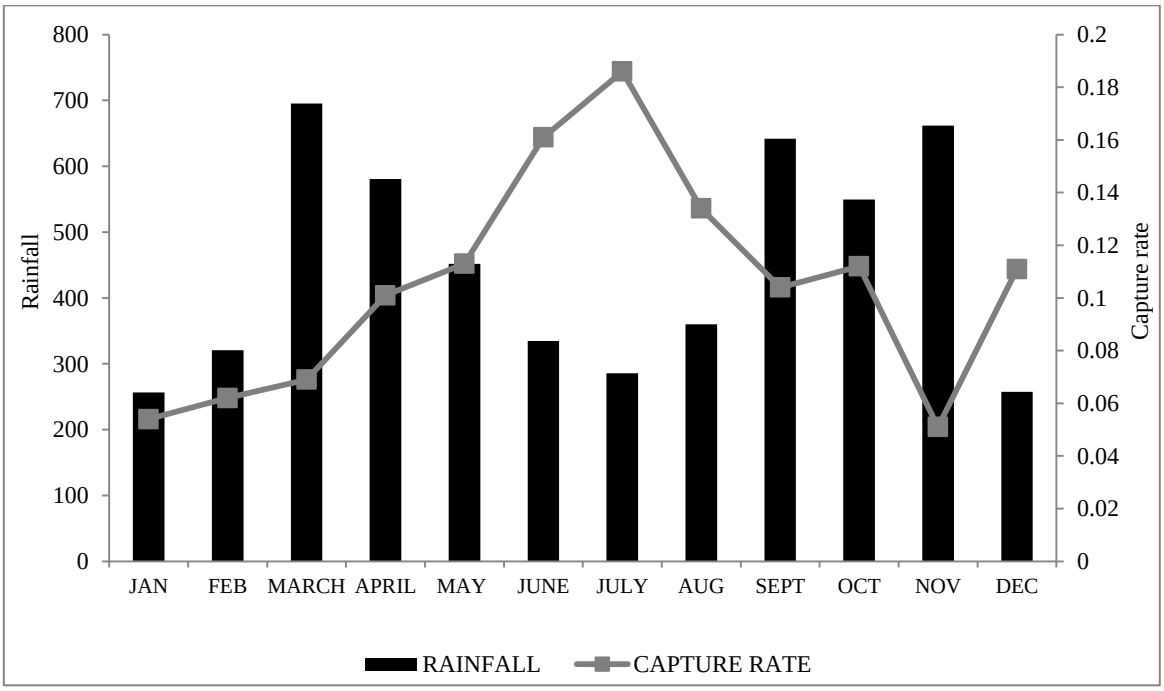

Figure 3.3-2: Monthly rainfall and bird's capture rate in UGFR

3.3.2 Rainfall and total birds in TFR

TFR recorded a total of 3030mm of rainfall which was contributed by an accumulated of 342 days of 2009 and 2010. In 2009, the total rainfall that was recorded is 1555mm, and this was contributed by 164 days while in 2010, 1474mm of total rainfall was contributed by 178 days. The wet seasons were recorded between March to April (average 157-186mm) and November to December (average 137-192mm) while dry seasons were recorded in January to February (average 106-108mm) and from May to August (average 86-131mm) (Figure 3.3-3).

During wet season, the lowest species abundance (62 birds of 17 species) (Figure 3.3-3) and capture rate (0.104 individual per hour) were recorded in December (Figure 3.3-4). During dry season, highest species abundance and capture rate were recorded in May and July (Figure 3.3-3) (Figure 3.3-4). May had recorded 211 birds (32 species) and capture rate 0.332 individual/hour; while July had 223 birds (25 species) and capture rate of 0.386 individual/hour. However, analysis showed that bird abundance and capture rate was not significantly correlated with rainfall (species and rainfall: $r=-0.364$, $p=0.237$) (capture rate and rainfall: $r=-0.322$, $p=0.297$) in 2009 and (species and rainfall: $r=0.323$, $p=0.297$) (capture rate and rainfall: $r=0.336$, $p=0.276$) in 2010.

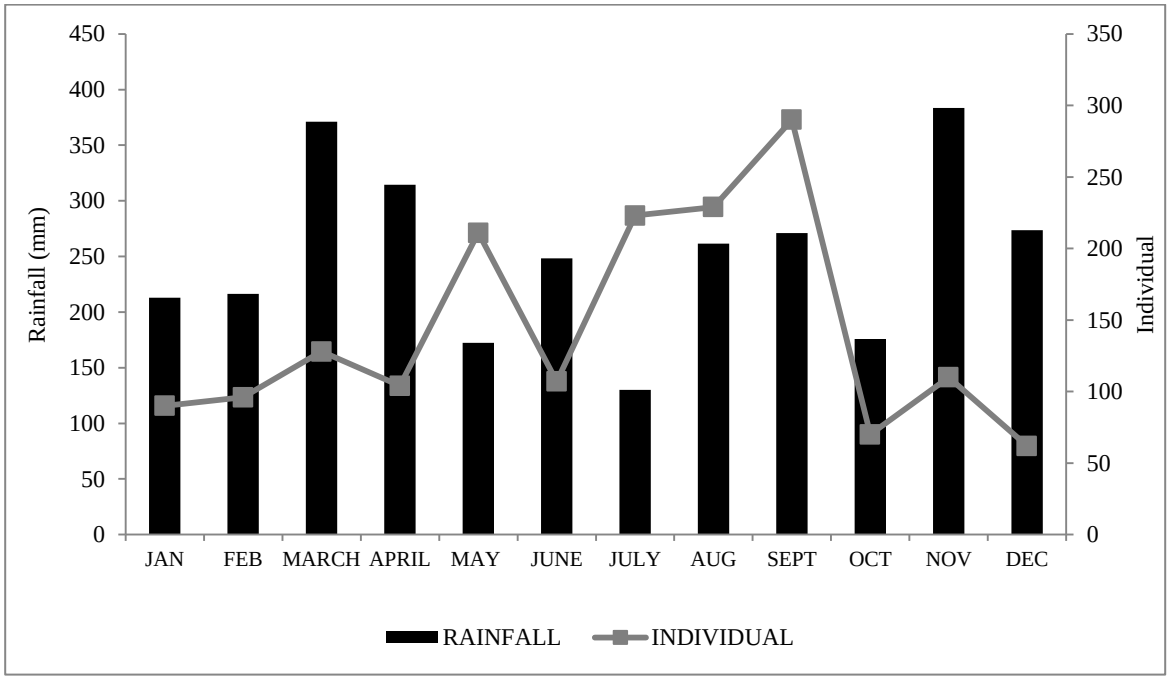

Figure 3.3-3: Monthly rainfall and total individuals in TFR

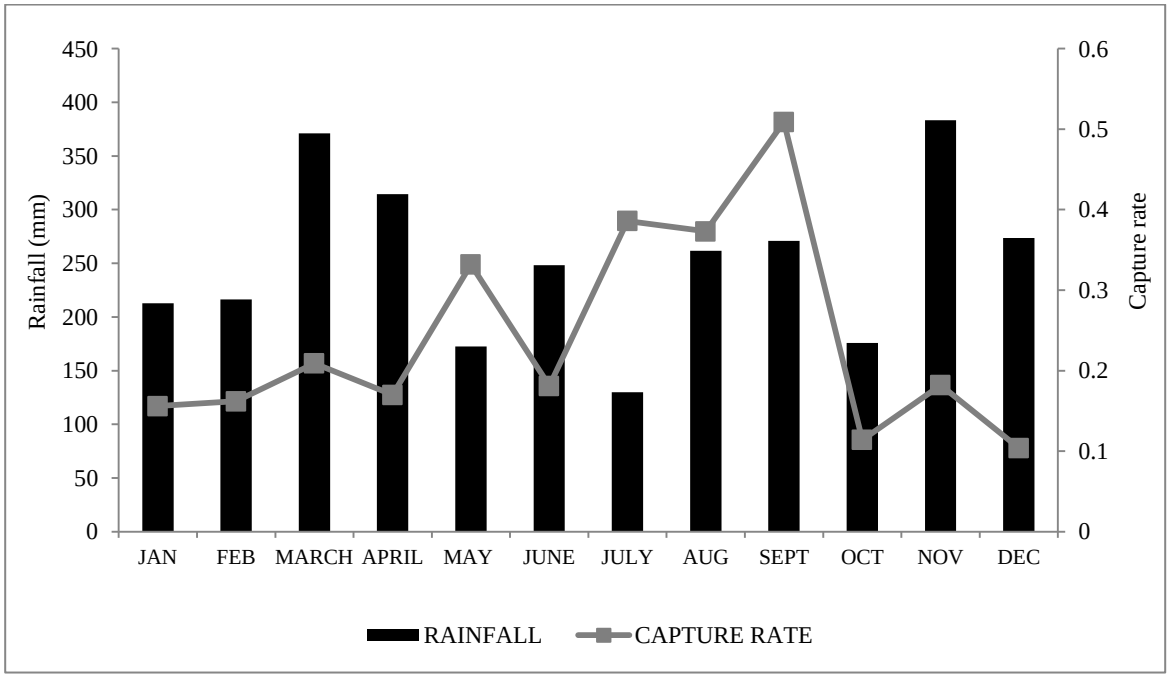

Figure 3.3-4: Monthly rainfall and bird's capture rate in TFR

3.4 Seasonal migration

3.4.1 Occurrence of migratory birds and resident/migratory populations

In total, there are 17 migratory species which were represented by 87 individuals and five resident/migratory population represented by 46 individuals were captured in both study sites. UGFR recorded 14 migratory species with 56 individuals and a resident/migratory species with three individuals. In TFR, nine species (represented by 54 individuals) were occurred as migrants while the remaining four species (20 individuals) have resident/migratory population. There is no significant difference in migratory species abundance of both study areas (Mann-Whitney U test, df=1, p=0.45).

3.4.2 Occurrence of migratory birds in UGFR during migratory season

In 2009, there are 36 birds belong to 14 migratory species were recorded while 23 individuals of eight migratory species were recorded in 2010. There is no significant difference of migratory species abundance in both years (Mann-Whitney U test, df=1, p=0.305). In 2009, the most abundant migratory birds were recorded in January and November with eight and six individuals respectively. In 2010, the migratory species were highly recorded in April and October with five individuals (22%) of three species respectively (Figure 3.4-1).

Siberian blue Robin (*Luscinia cyane*) recorded the highest individual captured with 12 birds. Five individuals were recorded in January, February, and October to November 2009 while seven individuals were captured in February to April, October, and December 2010. Nine individuals of Arctic Warbler (*Phylloscopus borealis*) were recorded in both years where three individuals were captured in November and December 2009 while remaining six individuals were captured in January, April and October 2010 (Figure 3.4-6). Six individuals of Mugimaki Flycatcher (*Ficedula mugimaki*) were captured. Five individuals were captured in May, September and October 2009 while one individual was trapped in December 2010. Tickell's blue Flycatcher (*Cyornis tickellia*) was the only species that has resident/migratory population in the study area. Two individuals of this species were captured in May and November 2009 (Figure 3.4-2).

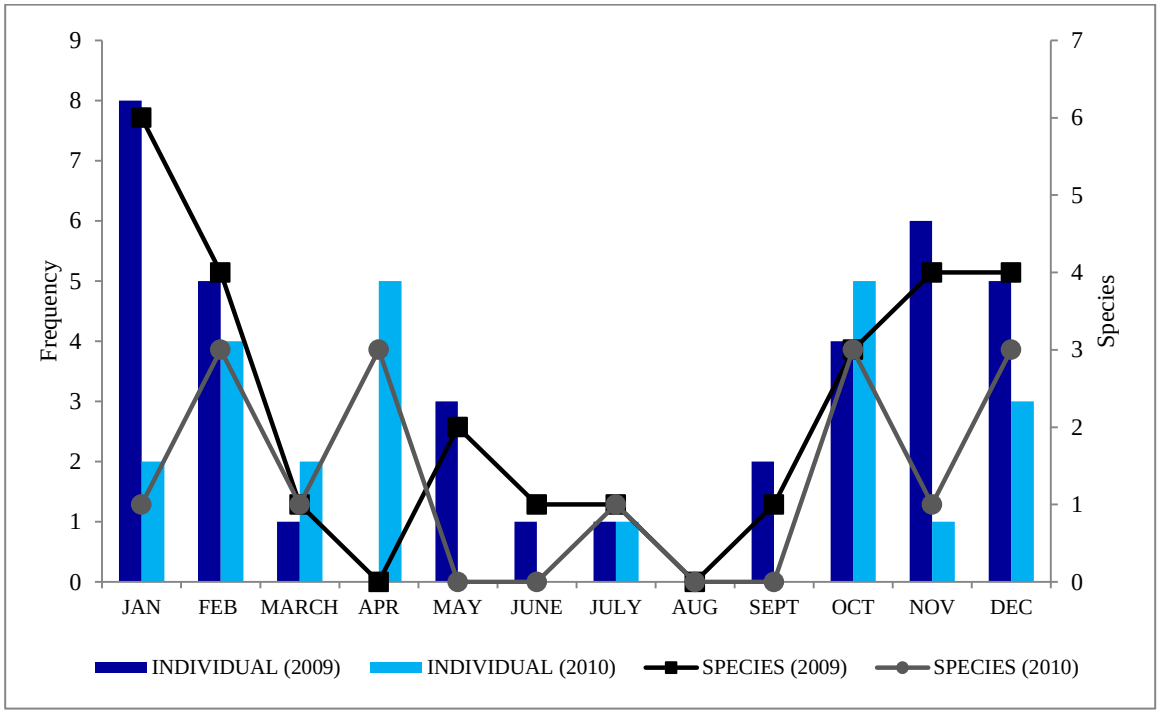

Figure 3.4-1: Monthly abundance of migratory birds species in UGFR

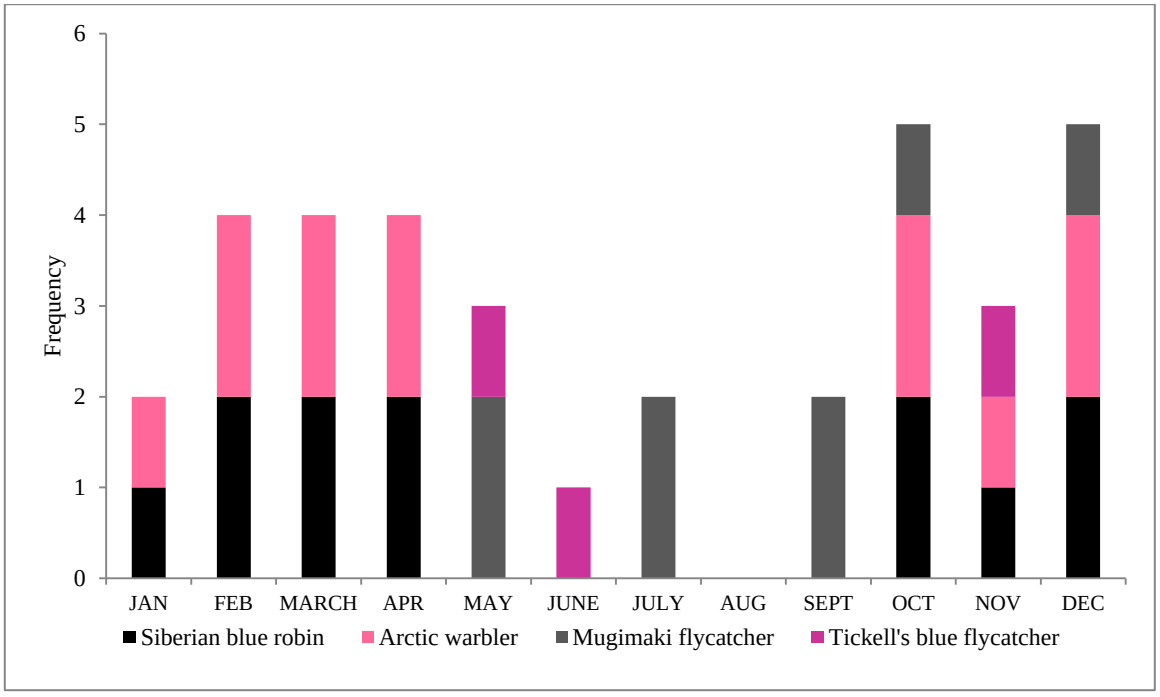

Figure 3.4-2: Monthly abundance of the most abundant migratory species and species that have resident/migratory population in UGFR

3.4.3 Occurrence of migratory birds in TFR during migratory season

Nine migratory species represented by 54 individuals and four resident/migratory species with 20 individuals were recorded in TFR. In 2009, 25 individuals of 10 species were recorded while in 2010, 49 individuals of 10 species were recorded. Migratory species abundance in both years are significantly difference (U=44.000, df=1, p=0.107). The migratory bird was highly captured in January to March and September to December. In 2009, the highest bird abundance was recorded in January with four individuals of three species, followed by September with three individuals of three species. In 2010, migrant was highly recorded in November with seven individuals of five species, followed by March with seven individuals of four species (Figure 3.4-3).

Siberian blue Robin (*Luscinia cyane*) was the most abundant migratory species captured in TFR with 17 individuals (23%). There are three individuals recorded in March and October 2009 while 14 individuals were recorded between January to March and September to November 2010. This was followed by Mugimaki Flycatcher (*Ficedula mugimaki*) with seven individuals. This species was represented by two individuals which were captured in April and December 2009 while five individuals were captured in May, November and December 2010 (Figure 3.4-4).

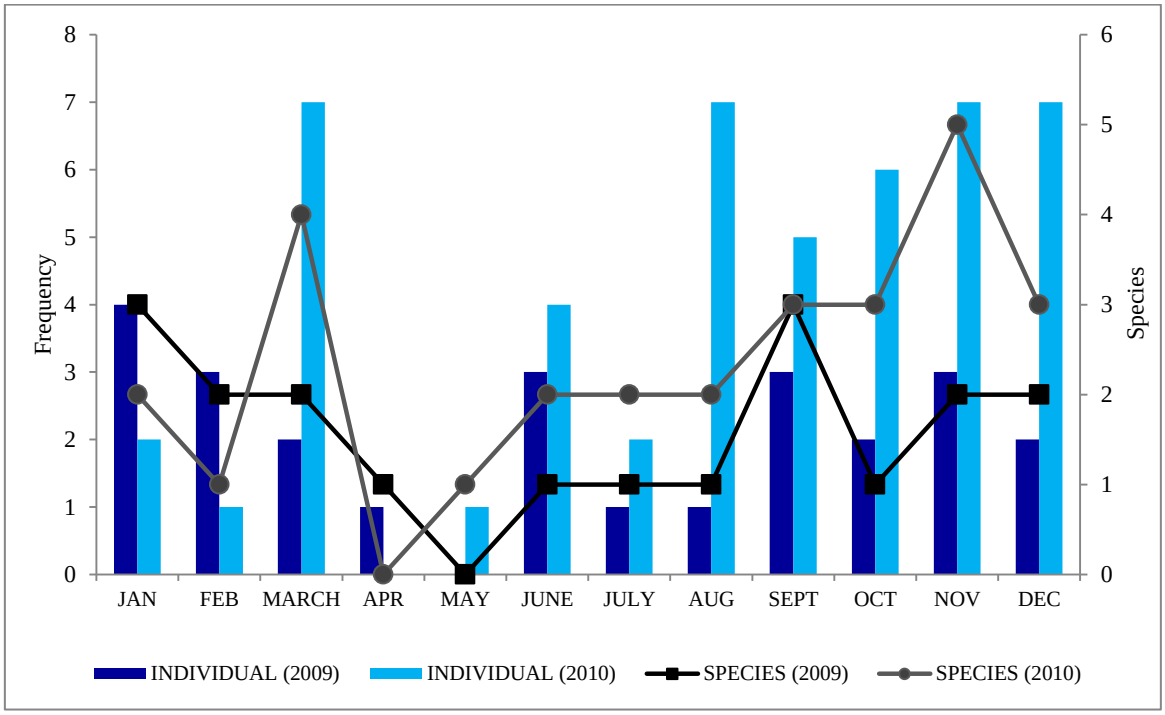

Figure 3.4-3: Monthly distribution of migratory bird species in TFR

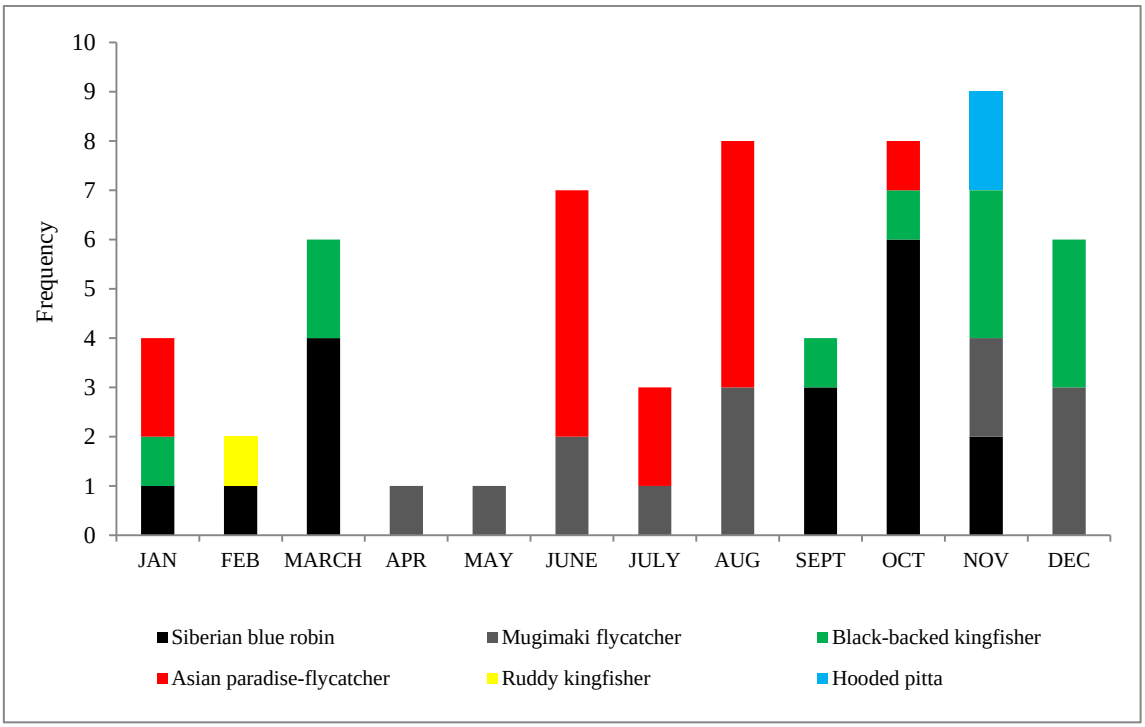

Figure 3.4-4: Monthly distribution of the most abundant migratory bird species in TFR

For resident/migratory birds population, it was dominated by Asian paradise Flycatcher (*Terpsiphone paradisi*) with three individuals. Two individuals were captured in January 2009 and one individual was captured in October 2010. This was followed by one individual of Ruddy Kingfisher (*Halcyon coromanda*) which was captured in February 2009 and two individuals of Hooded Pitta (*Pitta sordida*) which were captured in November 2009 and November 2010 (Figure 3.4-4).

3.4.4 Population of migratory birds during non-migratory season

Of 22 migratory species recorded in both study sites, four species were recorded outside migratory season (i.e from June to August). In UGFR, two species which were represented by three individuals were recorded between June to August. One individual of Tickell's blue Flycatcher (*Cyornis tickelliae*) was recorded in June 2009 (Figure 3.4-5) while two individuals of Mugimaki Flycatcher (*Ficedula mugimaki*) were recorded in July of both years (Figure 3.4-6). In TFR, two migratory species which were represented by 18 individuals were recorded during non-migratory season. Twelve individuals of Asian paradise Flycatcher (*Terpsiphone paradisi*) and six individuals of Mugimaki Flycatcher (*Ficedula mugimaki*) were recorded in June to August of both years (Figure 3.4-6).

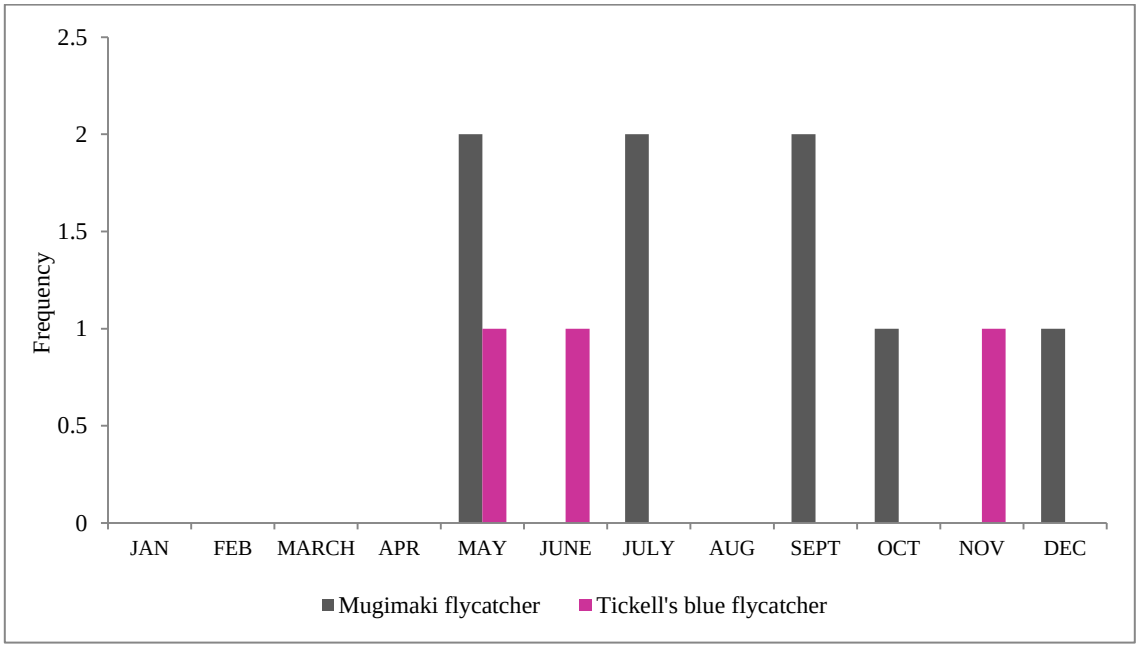

Figure 3.4-5: Occurrence of migratory birds during non-migratory season in UGFR

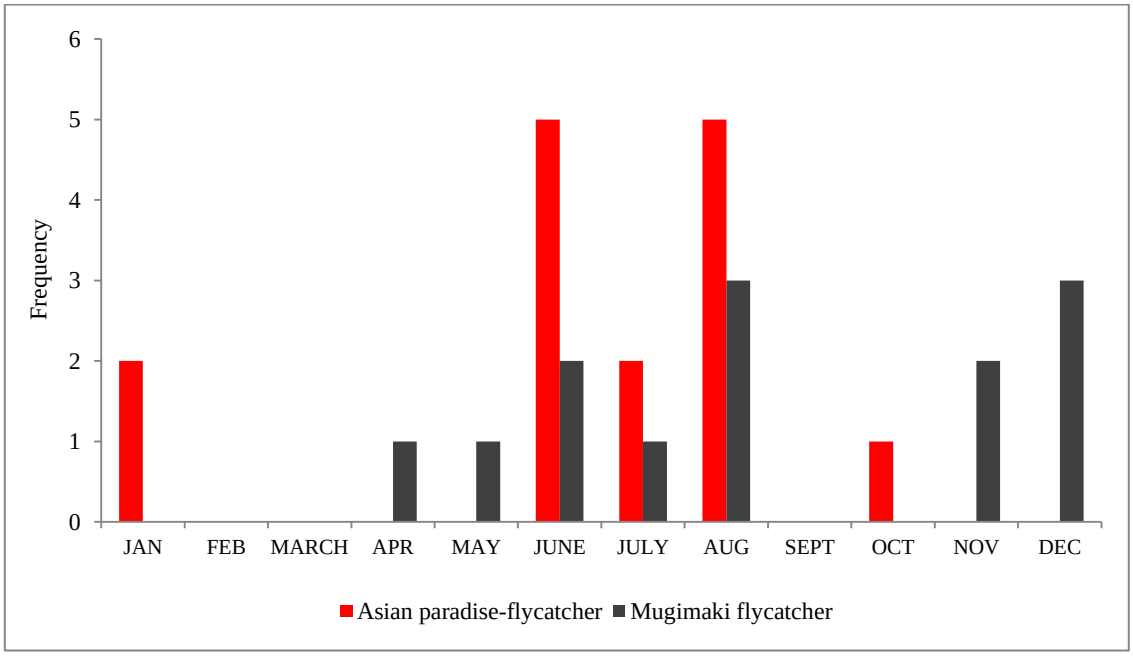

Figure 3.4-6: Occurrence of migratory birds during non-migratory season in TFR

3.5 Understorey birds assemblages in different habitats

3.5.1 Logged forest and Virgin Jungle Reserve (VJR)

Logged forest recorded higher species abundance (1,339 birds belong to 104 species of 28 families) compared to VJR (1,031 birds belong to 87 species of 24 families) (Figure 3.5-1). Likewise, logged forest recorded higher capture rate compared to VJR (0.093 versus 0.072). However, there is no significant difference between bird's species abundance of logged forest and VJR (Mann-Whitney U test, df=1, p=0.263).

3.5.1.1 Species composition

Family Pycnonotidae, Timaliidae and Muscicapidae formed biggest proportion of species captured in both habitats. The numbers of these species captured in logged forest were 15, 16 and 17, respectively. The numbers of species were slightly decreased in VJR with 10, 16 and 13 species were respectively recorded. (Figure 3.5-2 a-b). Family Nectariniidae recorded highest individual captured in both habitats with 503 individuals (38%) in logged forest and 226 individuals (22%) in VJR. This is followed by family Timaliidae which recorded 209 individuals (16%) in logged forest and 173 individuals (17%) in VJR.

Little Spiderhunter (*Arachnothera longirostra*) was mostly captured in both habitats with 623 birds (26%). Of these, about 33% or 436 individuals of this species were recorded in logged forest while 187 individuals (18%) were recorded in VJR. This was followed by Grey-throated Babbler (*Stachyris nigriceps*) with 39 individuals (3%) were recorded in logged forest while 46 individuals (27%) were captured in VJR. Rufous-backed Kingfisher (*Ceyx rufidorsa*) recorded 51 individuals (4%) in logged forest while 76 individuals (7%) in VJR.

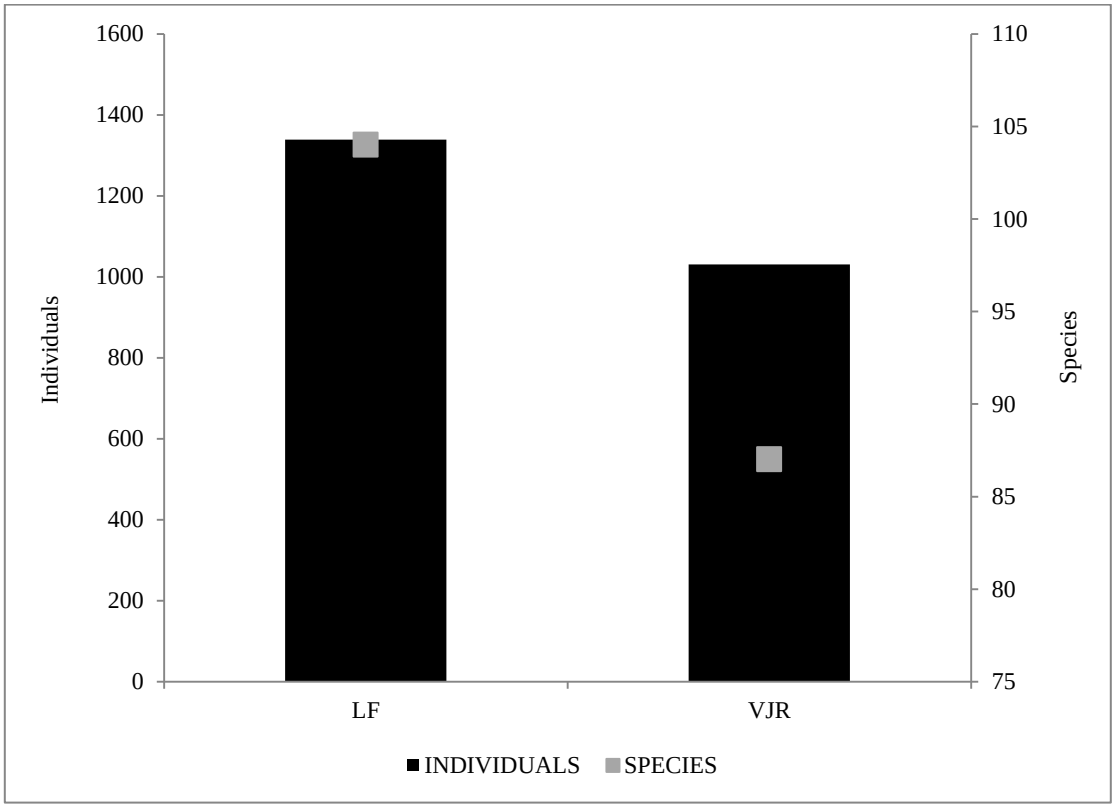

Figure 3.5-1: Capture rate and total number of birds and species captured in LF and VJRs of both study areas

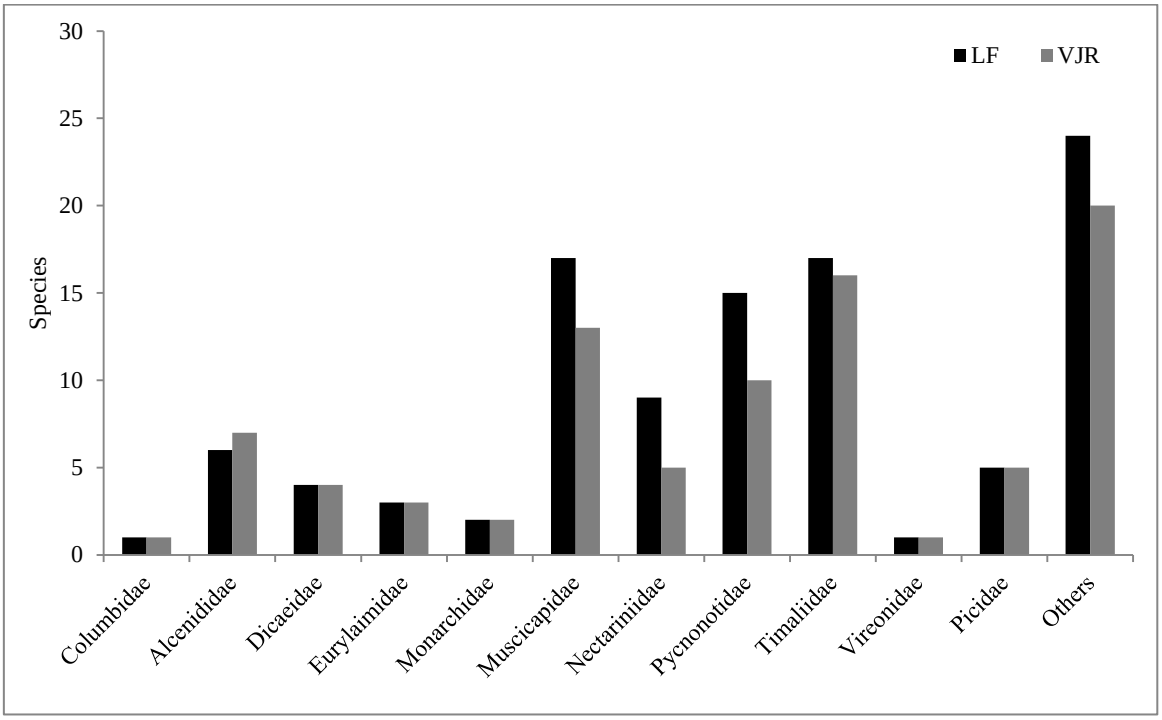

Figure 3.5-2(a): Number of bird species (by family) captured in logged forest (LF) and virgin jungle reserve (VJR)

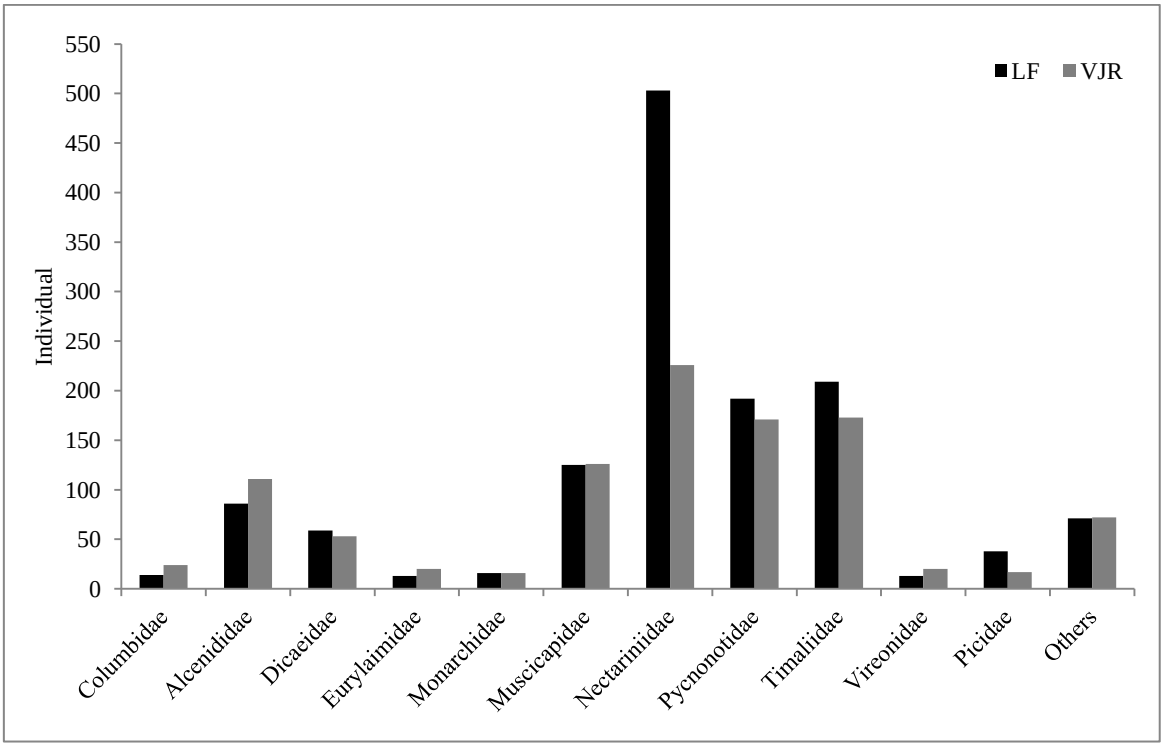

Figure 3.5-2(b): Number of bird individuals (by family) captured in logged forest (LF) and virgin jungle reserve (VJR)

Although VJR had lower capture rate than logged forest, it had recorded higher number of bird species. VJR bird's has higher evenness value and more diverse compared to logged forest (Simpson Evenness: 0.2175, Shannon-Weiner index: 3.616, Simpson D index: 0.946) (Table 3.5-1). Species accumulation curve had shown that none of the bird's population in both study sites had achieved asymptote. An increasing trend was shown by birds in both areas until the end of sampling period (Figure 3.5-3). This increasing trend is higher during early sampling but slowing down towards the end of sampling session.

Extrapolated species richness (using First-Order Jackknife) estimated same number of species in logged forest therefore the forest is well sampled. However, not all bird's species was captured in VJR since the estimator produces higher standard deviation and lower percentage of estimated species richness. This shows that birds in VJR were not adequately sampled compared to logged forest (Table 3.5-2). However, both habitats in UGFR have recorded almost same number of trapped species which indicated that these habitats are well sampled. However, both habitats in TFR recorded highest standard deviation which show that birds were not sufficiently sampled (Table 3.5-3).

Table 3.5-1: Diversity indices values of understorey birds inhabiting LF and VJR

Indices	LF	VJR
Berger-Parker Dominance (D_{BP})	0.3256	0.1814
Shannon-Weiner (H')	3.296	3.616
Simpson's Index (D)	0.882	0.946
Simpson Evenness	0.08182	0.2175

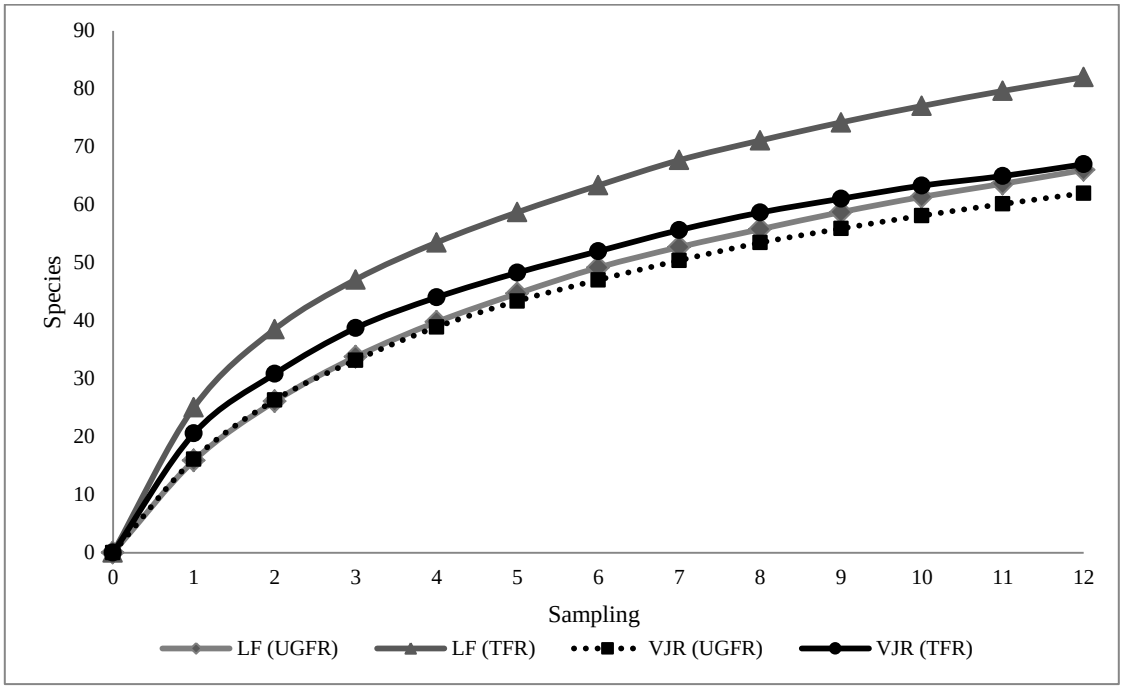

Figure 3.5-3: Species accumulation curve for understorey birds in different habitats of both study sites.

Table 3.5-2: First-order jackknife estimator of species diversity of understorey birds in different habitats (LF=logged forest, VJR=Virgin Jungle Reserve, SD=Standard deviation)

Habitat	Number of recorded species	First-order Jackknife	SD	Estimated species richness
LF	104	104	0	100%
VJR	87	144.5	8.5	60.2%

Table 3.5-3: First-order jackknife estimator of understorey bird in logged forest and VJR in UGFR and TFR (SD = Standard deviation)

Habitat/ Study sites	Number of recorded species	First-order Jackknife	SD	Estimated species richness
LF - UGFR	66	74	0	89%
LF - TFR	82	134	8	61%
VJR - UGFR	62	64	0	97%
VJR - TFR	66	110	2	60%

3.5.1.2 Uncommon species (singleton species)

There are four families which were represented by only one species or one individual. Family Oriolidae was represented by Dark-throated Oriole (*Oriolus xanthonotus*) which was found only in VJR of TFR. Family Falconidae was represented by Blyth's Hawk-eagle (*Nisaetus alboniger*) which was recorded only in LF of TFR. Family Motacillidae was represented by Western Yellow Wagtail (*Motacilla flava*) while Collared-scops Owl (*Otus lettia*) of family Strigidae were recorded only in LF of UGFR.

3.5.1.3 Species similarity of logged forest and VJR

Fifty-nine percent or 71 similar species were recorded in both habitats (LF and VJR) (Sorensen coefficient: 74%). Species abundance of both habitats were not significantly different (Mann-Whitney U test, df=1, p=0.82). These similar species were dominated by family Timaliidae (371 birds of 13 species); family Muscicapidae (242 birds of 12 species) and family Pycnonotidae (355 birds of 10 species).

Of all species, 14 species were significantly difference in abundance (x^2=2.75, df=1, p=0.01) between both habitats. Among these species, Little Spiderhunter (*Arachnothera longirostra*) is the most abundant (χ^2=3.89, df=1, p<0.05) where it was highly recorded in LF, followed by Rufous-backed Kingfisher (*Ceyx rufidorsa*) (χ^2=7.51, p<0.05) which was recorded more in VJR (Table 3.5-4). There are also presence of Near-threatened species such as Chestnut-naped Forktail (*Enicurus ruficapillus*) which was captured more in VJR while Buff-necked Woodpecker (*Meiglyptes tukki*) was higher in LF. Vulnerable species such as Brown-chested jungle Flycatcher (*Rhynomyias brunneata*) was captured more in VJR (Table 3.5-4).

In addition, there are also Near-threatened species occurred in low abundance in both habitats. These include Black-throated Babbler (*Stachyris nigricollis*), Chestnut-rumped Babbler (*Stachyris maculata*), Streaked Bulbul (*Ixos malaccencis*), Crested Jay (*Platylophus galericulatus*) and White-chested Babbler (*Trichastoma rostratum*) (Table 3.5-5).

Table 3.5-4: List of similar understorey birds species which has significant difference in species abundance between logged forest (LF) and virgin jungle reserve (VJR) using Chi-square test (χ^2).

COMMON NAME	LF	VJR	χ^2	p-value
Asian paradise Flycatcher	4	10	5.01	0.037
Brown-chested jungle-flycatcher	6	14	4.36	0.018
Buff-necked Woodpecker	22	6	5.59	0.017
Chestnut-naped Forktail	18	30	5.67	0.009
Chestnut-winged Babbler	35	13	6.85	0.020
Emerald Dove	14	24	5.42	0.016
Grey-cheeked Bulbul	34	45	5.81	0.018
Grey-throated Babbler	39	46	5.59	0.048
Little Spiderhunter	436	187	3.89	0.000
Plain Sunbird	9	1	47.81	0.031
Red-eyed Bulbul	21	2	4.63	0.001
Rufous-backed Kingfisher	51	76	11.49	0.000
Sooty-capped Babbler	4	14	13.35	0.004
Yellow-bellied Warbler	2	10	8.46	0.006

Table 3.5-5: List of Red-Listed birds (based on IUCN Red List) that were captured in logged forest (LF) and virgin jungle reserve (VJR). (NT=Near-Threatened, VU=Vulnerable)

COMMON NAME	LF	VJR	IUCN RED LIST
Rufous-collared Kingfisher	11	11	NT
Blue-banded Kingfisher	6	7	VU
Crested Jay	1	1	NT
Green Broadbill	10	14	NT
Chestnut-naped Forktail	18	30	NT
Brown-chested jungle-flycatcher	6	14	NT
Streaked Bulbul	1	4	NT
Grey-bellied Bulbul	6	5	NT
Short-tailed Babbler	13	10	NT
Sooty-capped Babbler	4	14	NT
Chestnut-rumped Babbler	3	4	NT
Black-throated Babbler	4	5	NT
White-chested Babbler	1	1	NT
Buff-necked Woodpecker	22	6	NT

3.5.1.4 Specialist species

There are 33 specialist species found only in LF while 16 species were found only in VJR. Most of the species occurred in low abundance, represented by less than 10 individuals. Family Muscicapidae has five species which were represented by eight individuals and were dominated by Hill-blue Flycatcher (*Cyornis banyumas*) and Grey-chested jungle-flycatcher (*Rhinomyias umbratilis*). Family Pycnonotidae was represented by five species consists of eight individuals which were dominated by Cream-vented Bulbul (*Pycnonotus simplex*) and Stripe-throated Bulbul (*Pycnonotus finlaysoni*). Family Timaliidae has six individuals of four species which were dominated by Horsefield's Babbler (*Malacocincla sepiaria*). Three Near-threatened species were represented by only single individual each. The species are Lesser green Leafbird (*Chloropsis cyanopogon*), Black-and-white Bulbul (*Pycnonotus melanoleucos*) and Red-throated Barbet (*Megalaima mystacophanos*) (Table 3.5-6). The remaining specialist species were classified as Least Concern.

In VJR, all specialist species were recorded in low abundance (below than 10 individuals for each species) and was dominated by Bronzed Drongo (*Dicrurus aeneus*) of family Dicruridae. Three species of family Timaliidae were recorded. It were dominated by Chestnut-backed Scimitar-Babbler (*Pomatorhinus montanus*) and a Near-threatened species, White-necked Babbler (*Stachyris leucotis*). Two species of Family Trogonidae were represented by three individuals and dominated by a Near-threatened species, Scarlet-rumped Trogon (*Harpactes duvaucelii*) (Table 3.5-6).

Table 3.5-6: List of specialist species that were classified under IUCN Red List which were captured in logged forest (LF) or virgin jungle reserve (VJR). (NT=Near-Threatened)

COMMON NAME	LF	VJR	IUCN STATUS
Lesser green leafbird	1	0	NT
Red-throated sunbird	1	0	NT
Dark-throated oriole	0	1	NT
Black-and-white bulbul	1	0	NT
Scaly-breasted bulbul	1	0	NT
Fluffy-backed tit-babbler	1	0	NT
White-necked babbler	0	2	NT
Red-throated barbet	1	0	NT
Diard's trogon	0	1	NT
Scarlet-rumped trogon	0	2	NT
Cinnamon-rumped trogon	2	0	NT

3.5.1.5 Species similarity of logged forest between UGFR and TFR

Of 104 recorded species in logged forest, 56% or 44 similar species represented by 1,191 individuals that belong to 14 families were present in logged forest of UGFR and TFR (Sorensen similarity coefficient = 60%). Most of the similar species were recorded more in TFR (Mann-Whitney U test, df=1, p=0.01). The similar species were dominated by Little Spiderhunter (*Arachnothera longirostra*) which was captured more in TFR (χ^2=3.15, df=1, p<0.05). Logged forest of TFR was also dominated by species such as Rufous-backed Kingfisher (*Ceyx rufidorsa*) (χ^2=3.15, df=1, p<0.05) and Red-eyed Bulbul (*Pycnonotus brunneus*) (χ^2=1.03, df=1, p<0.05). Near-threatened species such as Chestnut-naped Forktail (*Enicurus ruficapillus*) was commonly found in logged forest of UGFR (χ^2=10.23, df=1, p<0.05). UGFR was also dominated by Grey-throated Babbler (*Stachyris nigriceps*) (χ^2=29.32, df=1, p<0.05) and Grey-headed canary Flycatcher (*Culicicapa ceylonensis*) (χ^2=11.03, df=1, p<0.05).

3.5.1.6 Specialist species of logged forest

There are 22 specialist species were recorded only in UGFR. These specialist species were dominated by White-bellied Epornis (*Erpornis zantholeuca*) of family Vireonidae (13 individuals) and Pin-striped tit Babbler (*Macronus gularis*) of family Timaliidae (eight individuals). The remaining species such as Pale blue Flycatcher (*Cyornis unicolor*), Tickell's blue Flycatcher (*Cyornis tickelliae*) and Yellow-bellied Warbler (*Abroscopus superciliaris*) were occurred in low abundance (less than 10 individuals). Three Near-threatened species such as Streaked Bulbul (*Ixos malaccencis*), Scaly-breasted Bulbul (*Pycnonotus squamatos*) and Red-throated Sunbird (*Anthrepthes rhodolaema*) were represented by only single individual each.

A total of 38 specialist species were recorded only in TFR. The most common species are Scaly-crowned Babbler (*Malacopteron cinereum*) of Timaliidae (26 individuals) and Near-threatened species i.e Brown-chested jungle-flycatcher (*Rhinomyias brunneata*) of Muscicapidae (six individuals). The remaining species such as Long-billed Spiderhunter (*Arachnothera robusta*), Asian paradise Flycatcher (*Terpsiphone paradisi*), and a Near-threatened species such as Grey-chested jungle-flycatcher (*Rhinomyias brunneata*) and Black-throated Babbler (*Stachyris nigricollis*) were occurred in low abundance (i.e less than 10 individuals). Some Near-threatened species such as Fluffy-backed tit-babbler (*Macronus ptilosus*), Crested Jay (*Platylophus galericulatus*) and White-chested Babbler (*Trichastoma rostratum*) were represented by single individual only.

3.5.1.7 Species similarity between VJR of UGFR and TFR

A total of 41 species (888 individuals belong to 15 families) were recorded in VJR of both study areas (Sorensen similarity coefficient: 46%). The abundance of similar species were not significantly different in both study sites (Mann-Whitney U test, df=1, p=0.25) Species similarity was dominated by Little Spiderhunter where 90% of the species were recorded in TFR (χ^2=23.54, df=1, p<0.05). The abundance of Yellow-bellied Bulbul (*Alophoixus phaeocephalus*) (χ^2=1.72, df=1, p<0.05) and Scaly-crowned Babbler (*Malacopteron cinereum*) (χ^2=4.6, df=1, p<0.00) were significantly higher in TFR. Common species such as Rufous-backed Kingfisher (*Ceyx rufidorsa*) (χ^2=3.93, df=1, p<0.05), Grey-throated Babbler (*Stachyris nigriceps*) (χ^2=20.99, df=1, p<0.05), Hairy-backed Bulbul (*Tricholestes criniger*) (χ^2=7.34, df=1, p=0.05) were captured more in UGFR. Uncommon species such as White-bellied Erpornis (*Erpornis zantholeuca*) (χ^2=8.94, df=1, p<0.05) and Arctic Warbler (*Phylloscopus borealis*) (χ^2=2.77, df=1, p<0.05) were recorded higher in UGFR.

3.5.1.8 Specialist species of VJR

Twenty-one specialist species were captured only in UGFR and this was highly dominated by Yellow-bellied Warbler (*Abroscopus superciliaris*) of family Cettidae (10 individuals), Grey-eyed Bulbul (*Iole propinqua*) of Pycnonotidae (nine individuals) and Rufous Piculet (*Sasia abnormis*) of family Picidae with six individuals. All species occurred in low abundance but two species, White-necked Babbler (*Stachyris leucotis*) and Diard's Trogon (*Harpactes diardii*) are Near-threatened.

There are 25 specialist species were captured only in TFR. Of these, family Eurylaimidae formed major proportion with 20 individuals that belong to three species. The most common birds are Green Broadbill (*Calyptomena viridis*) of family Eurylaimidae (14 individuals), Chestnut-winged Babbler (*Stachyris erythroptera*) of Timaliidae (13 individuals) and Asian paradise Flycatcher (*Terpsiphone paradisi*) of Monarchidae (10 individuals). The remaining species occurred in low abundance (less than 10 individuals) including a Vulnerable species such as Blue-banded Kingfisher (*Alcedo euryzona*), and four Near-threatened species such as Black-throated Babbler (*Stachyris nigricollis*), Chestnut-rumped Babbler (*Stachyris maculata*), Dark-throated Oriole (*Oriolus xanthonotus*) and Crested Jay (*Platylophus galericulatus*).

CHAPTER 4: DISCUSSION

4.1 Understorey birds assemblages in UGFR and TFR

Differences in species composition in each study area was influenced by spatial and temporal variations. Community structures are more or less similar between both study areas but species composition was different depending on differences in topography, vegetation structure, microclimate, food availability, degree of disturbances and history of logging (Mohamed Zakaria, 2002, Fernandez-Juricic, 2004, Peh, 2005). Results indicate that family Timaliidae, Muscicapidae, Pycnonotidae and Nectariniidae formed biggest proportion (50%) of the captured species. Forest understorey was dominated by forest birds such as Timaliidae (babblers) and Muscicapidae (flycatchers) (Johns, 1986). Secondary forest or disturbed habitat was dominated by secondary and colonizer species such as Pycnonotidae (bulbuls) and Nectariniidae (spiderhunters) (Hisashi Nagata, 1997, Zamri, 2002).

Ulu Gombak Forest Reserve (UGFR) are more diverse than Triang Forest Reserve (TFR) mainly because the latter forest was dominated by Little Spiderhunter (*Arachnothera longirostra*). Recent logging activity (less than 10 years) in TFR had triggered extensive growth of bananas and gingers along the forest track and forest edge. These areas are frequently visited by Little Spiderhunter. The species was frequently recorded in regenerating to mature forest, edge vegetation along forest tracks, streams and clearings, especially where pioneer species of bananas and gingers are luxuriously growth (Wells, 2007). Despite being logged, the remaining untouched forest (VJR) still harbor some primary forest species such as Short-tailed babbler (*Malacocincla malaccencis*),

Brown-chested jungle Flycatcher (*Rhinomyias brunneata*) and Black-throated Babbler (*Stachyris nigricollis*) that survive local extinction.

UGFR facing higher impacts of disturbance due to rapid urbanization and development of surrounding areas. However, the presence of primary forest species such as babblers and flycatchers suggested that regeneration process that takes place in this forest was able to harbor primary forest species. Regeneration process of UGFR (after 50 years of logging activities) makes the forest vegetation are more or less resembled primary forest. Previous study indicated that any forests that have been regenerated for 25 to 30 years will have more advance forest structure compared to those recently logged (Wong, 1986). Species such as Moustached Babbler (*Malacopteron magnirostre*), Pin-striped tit Babbler (*Macronus gularis*) and Short-tailed babbler (*Trichastoma malaccense*) were recorded in UGFR by Medway (1965), Bransburry (1997) and this study. It shows that these species were able to survive in this forest despite been logged.

Differences in topographical structure of the study area also contributed to the differences in species composition. Grey-throated Babbler (*Stachyris nigriceps*) was common in UGFR because their preferable habitat is available. Although this species prefers submontane and montane elevations, it also occurs in hilly area of lowland forest such as in UGFR. The valley areas are preferable habitat for Chestnut-naped Forktail (*Enicurus ruficapillus*) and Rufous-backed Kingfisher (*Ceyx rufidorsa*). These species favor forest stream and damp ground where they can forage on small fish, small annelids, insects and spiders. Since the forest was fragmented by roads, secondary forest species such as bulbul were recorded more in disturbed area in UGFR than TFR. This is because the species were able to occupy modified habitat and had successfully adapted to forest structure caused by logging process.

Forest size also plays important role in species persistent. Larger size increases species persistent while smaller area favors species turnover (Fernandez-Juricic, 2004, Sodhi, 2007). Larger forest contains diverse species composition because of high quantity and quality of existing forest (Sodhi, 2004). The size of TFR is approximately three times of UGFR and it is believed that this study has not managed to capture all understorey species occupying the area. Species accumulation curves for both sites are not reaching asymptote although it is estimated that all birds species in UGFR were sampled. Number of sampling should be increase in future study in order to capture all possible understorey birds occupying both forest reserves but this was impossible for this study due to time constraint. Even with 48 samplings, this study had successfully sampled 28% of total forest associated species. Most of the captured species were understorey birds and therefore the results supported the choice of method chosen in capturing understorey birds. Standardized mist netting is the most efficient method in capturing small birds inhabiting dense vegetation, which is usually difficult to record capture especially outside breeding season.

More than 50% of species similarity between study indicated that both habitats are more or less resemble in habitat preference. However, the abundance of similar species were different. Presence of Near-threatened species such as Green Broadbill (*Calyptomena viridis*), Grey-bellied bulbul (*Pycnonotus cyaniventris*) and Black-and-white Bulbul (*Pycnonotus melanoleucos*) indicated that regenerated and newly-logged habitats are capable in harboring important species. Presence of these species especially frugivores may assist in seed distribution to allow better regeneration process in disturbed forest (Levey, 1988, Peh, 2007). Forest ecosystem of both reserves are important in maintaining survival of globally threatened species. In addition, other species which are listed as Least Concern should not be neglected as if might be facing local extinction.

Feeding guild composition in both study areas was dominated by insectivorous birds which mainly comprises of primary forest birds of family Timaliidae (babblers). More than 50% of babblers such as Moustached Babbler (*Malacopteron magnirostre*), Scaly-crowned Babbler (*Malacopteron cinereum*) and Chestnut-winged Babbler (*Stachyris erythroptera*) are foliage gleaning insectivores. These species were vulnerable to habitat changes due to their physiologically ill-adapted to microclimate changes and food scarcity (Zakaria, 2001). However, these species were presence in high abundance indicated that both forest reserves are providing adequate food resources and suitable microclimate in attracting these sensitive species. It also shows that the forest are in recovery process although TFR has been logged for less than 10 years. Presence of these important species indicated that the study area can harbor vulnerable species despite changes caused by logging activities.

Frugivorous/insectivorous birds are common in disturbed habitat due to their ability to switch their diet between fruit and insect (Mohamed Zakaria, 2002). These species can tolerate high temperature and light intensity (Zakaria, 1998), therefore the birds are more attracted to utilize resources at forest-edge or gap (Levey, 1988). Bulbuls such as Hairy-backed Bulbul (*Tricholestes criniger*), Yellow-bellied Bulbul (*Alophoixus phaeocephalus*) and Spectacled Bulbul (*Pycnonotus erythrophthalmus*) which are abundant in regenerated forest (Wells, 2007) consumed mainly figs (*Ficus*) and small fruit of edge pioneers including *Macaranga* sp. They also feed on insects that were flushed out from the visited tree.

Although UGFR was in regeneration process for about 50 years, level of disturbances that occurred surrounding this area had lessen the impact of forest recovery. Extensive growth of succession species such as banana (Musaceae) and gingers

(Zingiberaceae) at forest edge, gap or along logging tracks of newly-logged forest (TFR) had attracted more nectarivorous/insectivorous birds. However, the extensive growth may create cool and humid condition that characterized understorey of VJR (Johns, 1989). This condition not only attracted generalist species (nectarivorous/insectivorous) but also also according to Johns (1989), it allowed reestablishment of understorey species such as foliage-gleaning insectivores (for example babblers of the genus *Stachyris*).

4.2 Monthly variation in relation to rainfall and migratory season

Results indicated that monthly distribution of birds in both years were not significantly different in both study areas. Birds are abundant from May to September and reached its highest peak between June and July. Food abundance is an important factor for avian phenology (Yap et al., 2007). Increased food abundance would trigger breeding cycles and molting. Based on feeding guild composition, frugivorous and insectivorous species formed biggest proportion during peak. Several environmental factors such as rainfall and food abundance (fruiting, flowering trees and arthropods availability) influence bird species abundance and temporal distribution in specific habitat. Further study on the effect of habitat disturbances can be conducted to compare food abundance with avian breeding to gather full information on avian distribution.

Tropical rainforest of Southeast Asia experienced aseasonality which does not suffer a regular dry season with mean rainfall is less than 100 mm. The study areas experienced minimum rainfall (dry season) during highest peak of birds abundance and lower capture rate during maximum rainfall (wet season). However, correlation analysis between rainfall and bird species abundance of both years indicated insignificant relationship. Therefore, it can be concluded that rainfall had no influence on species

distribution. Although species richness was apparently low during wet season, this is associated with sampling efforts. All mist-nets were closed during heavy rain to avoid adverse effects on trapped birds. Therefore, sampling hours are reduced during heavy rain, thus decrease capture rate.

Most migratory species choose coastal areas or freshwater swamps as their preferable stopover site. However, the present of small numbers (18%) of migratory species in study sites should not be neglected. The presence of these migrants indicate that the study areas were suitable for stopover sites of particular species. Most of common migrants which were recorded in well-known stopover sites such as Fraser's Hill and Cameron Highlands (Strange, 1993) were recorded in this study. The species included Mugimaki flycatcher, Hooded pitta, Ruddy kingfisher, Brown shrike and Tiger shrike.

The abundance of regular and common non-breeding visitor, Siberian blue Robin (*Luscinia cyane*) in both study areas during migratory period indicate that both areas were suitable as preferable stopover site. This is because both reserves provide resources that met migratory species requirements such as food resources (mainly insects) and place for resting. This species frequent forest floor of regenerating to mature and secondary old growth of lowland forest, and also occurs in montane forest up to 1500 m (Wells, 2007). This species was spending their daylight period on the forest ground forage for food (Strange, 1993, Wells, 2007). In this study, the species was recorded from January to April and September to December with the heaviest captured was found in October. The findings are in line with previous studies in several places such as Fraser's Hill (Strange, 1993) and Pasoh Forest Reserve (Wells, 2007). In Pasoh, a few overwinterers were still present in late April.

Passage migrant such as Arctic Warbler (*Phylloscopus borealis*) is a common and regular non-breeding visitor at all elevations up to montane ecotone. The species frequent mature, disturbed and secondary growth of lowland forest (Wells, 2007). The species was listed as forth commonest migrant in Gombak forest slope. It was reported to be found in ridge forest (about 1000m) at Genting Highlands in October (Wells, 2007). In this study, the species was recorded during January to April and October to December. The finding are in line with previous study that reported high abundance of this species in Fraser's Hill and other Main-range stations during October to November (Wells, 2007).

Mugimaki Flycatcher (*Ficedula mugimaki*) is a regular passage migrant and this non-breeding visitor was reported abundantly presence in late December to March. The last returning passage peaks was recorded in April (Wells, 2007). However, in this study the species had been recorded in low abundance outside migratory period from June to August in both study areas. This species may arrive in early autumn and returned during late spring. Shifting in timing of migration may be affected by changes in climatic pattern in origin habitat (Cotton, 2003, Gordo, 2007). Long term study also need to be conducted in both study areas to investigate the arrival and departure of this species and also distribution during migratory and non-migratory season.

Although the abundance of migratory species is low, the function of forest reserves in providing potential stopover site to migratory birds should not be neglected. Habitat quality should be maintained to fulfill the requirements needed by migrants during their migratory journey. Birds that use their environments in similar ways should be expected to select similar environmental features (Tankersley, 2004). Variability of resources at different location and time had forced birds to adapt with the changes. Habitat association with bird species was not only influenced by food resources, but also related to forest

microclimate, forest structure, predation and food availability (Sekercioglu, 2002). Therefore, forest management should take into account of maintaining and improving forest ecosystem in order to preserve and conserve the avifauna.

4.3 Understorey birds assemblages in different habitats

Different levels of forest disturbance that occurred in primary forest may affect forest ecosystem and birds communities. Many original species may survive in altered habitat but some may reduce or loss due to poor resilience towards disturbance (Sodhi et al., 2005). Ability to withstand habitat alteration will ensure original species to survive in harsh condition. Degraded forest may sustain primary species depending on disturbance history and quality of remaining forest, although species composition may changed (Sodhi et al., 2005). The most important factor is the ability of avifauna to maintain its reproductive population in degraded habitat. Modification of forest structure, microclimate and food resources due to logging activities had increase the abundance of secondary or colonizer species which were able to tolerate harsh environment (Mohamed Zakaria, 2002).

Forest gaps which resulted from logging activities enabled more sunlight to penetrate to the forest floor, which caused changes in vegetation structure of the forest floor. Fleshy fruiting trees abundance increased after logging resulting from increasing sun exposure to forest floor (Owiunji and Plumptre, 1998). At the same time, triggered undergrowth trees to flower and produce fruit and this would attract frugivorous and nectarivorous species such as bulbuls (Pycnonotidae) and spiderhunters (Nectariniidae) (Levey, 1988). Gaps can be an important sources of fruits whenever the fruit resources are scarce because it provided high diversity and long fruiting plants (Levey, 1988). Secondary

and forest edge species numbers increased in gaps than forest-interior species (Levey, 1988). Forest edge species such as Red-eyed Bulbul (*Pycnonotus brunneus*) and Little Spiderhunter (*Arachnothera longirostra*) can tolerate high temperature and light intensity during feeding and this makes them more common in disturbed and regenerating forest (Mohamed Zakaria, 2002, Wells, 2007).

Although results indicated that logged forest harbor more bird species (which was dominated by colonizer species), present of primary species such as babblers and flycatchers should not be neglected and may be useful for forest management practice. Presence of insectivorous species such as Moustached Babbler and Chestnut-winged Babbler in logged forest showed that the habitat able to harbor shade-tolerant species. These species were reported intolerant to microclimate changes and food scarcity due to habitat disruption (Zamri, 2002). Forest-interior species are reluctant to cross forest gaps or roads due to lack of ability to adapt habitat changes and increase risk of predation along the forest edge (Thinh et al., 2012a). Habitat barriers may inhibit movement and dispersal of forest-interior species across habitat while most generalist species were attracted to the exposed area (Thinh et al., 2012a). Therefore, the specialist species are vulnerable to habitat changes and may be extinct due to failure to adapt to the new surroundings.

Comparison between understorey bird communities of logged and unlogged forests concluded that species composition in logged forest almost similar to unlogged forest but differ in density (Owiunji and Plumptre, 1998, Peh, 2005, Mohamed Zakaria, 2005). Percentage of species similarity between LF and VJR was higher (60%) and it was dominated by common understorey families such as Timaliidae, Pycnonotidae, and Muscicapidae. The percentage of species similarity between LF versus LF of different study sites was higher compared to VJR versus VJR. The higher percentage similarity in

LF was due to the domination by few common secondary species such as Little Spiderhunter and Hairy-backed bulbul. Population of these species were decreased in VJR. Presence of forest-interior species such as Green Broadbill (*Calyptomena viridis*) and Crested Jay (*Platylophus galericulatus*) in logged forest indicate that the forest had regenerated and able to mitigate species loss.

This study recorded Grey-chested jungle flycatcher (*Rhynomias umbratilis*) and Grey-headed canary Flycatcher (*Culicicapa ceylonensis*) in logged forest. Previous study shown that both species were not recorded in recently logged forest (below 12 year-old) in Peninsular Malaysia (Johns, 1986, Johns, 1989). However, these species were recorded in 30-years old logged forest in Bekok and Belumut (Peh, 2005). This support that primary forest species are able to recolonize regenerated forest over time. Different species require different period to adapt and establish its population in regenerated forest. Some primary forest species may use adjacent habitat (secondary forest or degraded habitat) to exploit available food resources but still depending on primary forest for nesting and breeding (Jeyarasingam, 1998). Study in degraded habitats in Java had shown that less than 50% of persisting lowland birds breed in moderately degraded habitat based on the proportion of breeding adults in selectively-logged and secondary forests (Sodhi et al., 2005).

Species may become rare or uncommon in a particular habitat due to lack of food resources or optimal living space (Johns, 1986). In this study, representatives of several families such as Oriolidae, Motacillidae, Falconidae, Strigidae and Cuculidae were rarely recorded. These uncommon species were not recorded by mist nets because it consists of nocturnal or migrants species, or it utilizes middle and canopy levels. Species such as Banded broadbill (*Eurylaimus javanicus*), Asian fairy bluebird (*Irena puella*), and Rusty-breasted cuckoo (*Cacomantis sepulcralis*) usually frequent middle storey and forest

canopy which allow them to escape mist nets. On the other hand, members of families Laniidae (shrikes) and Turdidae (thrushes) were rarely sampled because they are migrants. These species were recorded in this study at low abundance and only at specific sites because they are influence by the availability of food resources and suitable habitat.

The presence of raptors such as Blyth's Hawk Eagle (*Nisaetus alboniger*) in mist nets was quite surprising. This species is not susceptible to mist netting method. It was trapped when trying to snatch another bird which was mist-netted. The species frequently seen wandering throughout the lowlands forest and crossing habitat gaps in searching for prey (Wells, 2007). It hunts from canopy level down to mid-stratum level and sometimes extended to only few meters above the bank or forest trails (Wells, 2007). The presence of non-forest species such as Western Yellow Wagtail (*Motacilla flava*) in secondary forest shows that the level of disturbance by human in particular area was very high. Sampling point where the species was captured is located nearby the quarry. Therefore, it can be suggested that development and urbanization process at nearby forested areas may increase the level of habitat perturbation, thus increase disturbance on specialist species in the area.

Secondary forest has the potential in conserving primary forest birds by functioning as surrogate habitat for primary forest if the forest were allow to regenerate (Castelletta, 2005, Peh, 2005, Dent, 2009). Primary forest species will colonize secondary forest at different times during succession. Long-term studies in Peninsular Malaysia showed that birds species richness was lower in 25-year old regenerating logged forest than in primary forest (Wong, 1986). Secondary forest which had undergone recovery approximately 20-40 years ago may have species assemblage resembled to primary forest (Dunn, 2004). Any logged forest that was left untouched can play an important role in conserving primary forest species.

The presence of Red-Listed species in any habitat should attract more attention for conservation and monitoring purposes. The checklist of Red-listed species is useful in analyzing the effect of habitat disturbances towards primary forest bird. Conservation effort should focus more on primary forest birds because there is no substitute for primary forest once it had been disturbed even with relatively small impact (such as selective logging). Nonetheless, the value of secondary forest should not be neglected because it also can play an important role in biodiversity conservation especially when it is located close to the primary forest. Preservation and conservation of existing lowland forest patches are crucial for long-term survival of avifauna either in Malaysia or throughout Southeast Asia.

CHAPTER 5: CONCLUSION

This study has examined understorey birds assemblages in different habitats (logged forest and virgin jungle reserve) in two selected lowland forests. The relationships between rainfall and migratory season on understorey birds assemblages were studied. A total of 2,370 individuals belong to 120 species and 30 families were recorded. This study was conducted over a span of 24 months or 48 sampling in two study sites.

Results in this study shows that birds of family Timaliidae, Muscicapidae, Pycnonotidae and Nectariniidae had formed biggest proportion of species abundance. Family Pycnonotidae and Nectariniidae were known as secondary or colonizer species therefore these species were abundant in secondary forest or newly-logged forest. However, increasing number of these species in Virgin Jungle Reserve (VJR) had raised a question on quality of the undisturbed forest. This was supported by more than 50% of species similarity between logged forest and VJRs.

Based on observation, this situation might be contributed by location of VJRs and logged forest whether both are located in short distance or intact. Besides, there are also formation of logging road adjacent to VJR compartment which contribute to the increasing numbers of secondary bird species. However, presence of primary forest birds such as babblers (Timaliidae) and flycatchers (Muscicapidae) in logged forests indicated that potential of the forest to harbor the forest-dependent species. Secondary forest can play an important role in biodiversity conservation especially when the forest are adjacent to VJR or allowed for regeneration in sufficient time (Peh, 2005). Role of VJRs are important to support the persistence of forest-dependent species especially when it is located nearby disturbed habitat. Therefore, the presence of primary forest birds in VJRs indicated that the forest are able to maintain its quality to harbor the sensitive species.

Rainfall has not greatly influence distribution of understorey birds. Decreasing capture rate during heavy rain was contributed by sampling effort. The nets were closed during heavy rains thus decreasing the capture rate. Presence of migratory species in study areas indicated that the study areas were suitable site for stopover of particular species. Most of common migrants such as Mugimaki flycatcher, Hooded pitta, Ruddy kingfisher, Brown shrike and Tiger shrike which were recorded in well-known stopover sites such as Fraser's Hill and Cameron Highlands (Strange, 1993) were recorded in this study. Presence of migratory species outside migratory season might be influenced by early arriving or late departure. Changes in climatic pattern in origin habitat might contributed to the shifting in timing of migration (Cotton, 2003, Gordo, 2007)

The assessment on birds assemblages in disturbed areas are important to give idea on how extensive the level of disturbances. Differences in birds assemblages was mainly contributed by differences in habitat structure. Although this study was carried out in short period, the findings may give an idea on community structure and will help in forest management practice for conservation purposes. Long-term studies are needed to assess overall community structure covering forested area. Further study also can be conducted to examine other factors contributing such as food resources and microclimate changes.

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Appendix: Relative abundance of understorey birds captured in logged forest (LF) and virgin jungle reserve (VJR) of Ulu Gombak Forest Reserve (UGFR) and Triang Forest Reserve (TFR)

SCIENTIFIC NAME	COMMON NAME	Logged forest		VJR	
		TFR (10 years)	UGFR (30 years)	TFR	UGFR
Abroscopus superciliaris	Yellow-bellied warbler	0	0.0060	0	0.0252
Actenoides concretus	Rufous-collared kingfisher	0.0080	0.0090	0.0095	0.0126
Aethopyga temminckii	Temmick's sunbird	0.0020	0	0	0
Alcedo euryzonia	Blue-banded kingfisher	0.0040	0.0060	0.0110	0
Alcedo meninting	Blue-eared kingfisher	0.0030	0	0.0047	0
Alophoixus bres	Grey-cheeked bulbul	0.0229	0.0328	0.0457	0.0403
Alophoixus phaeocephalus	Yellow-bellied bulbul	0.0229	0.0328	0.0457	0.0202
Anthreptes rhodolaema	Red-throated sunbird	0	1	0	0
Anthreptes simplex	Plain sunbird	0.0070	0.0060	0.0016	0
Anthrepthes malacensis	Brown-throated sunbird	0.0020	0	0	0
Arachnother aaffinis	Grey-breasted spiderhunter	0.0100	0.0060	0.0079	0.0101
Arachnothera longirostra	Little Spiderhunter	0.4183	0.0478	0.2634	0.0504
Arachnothera robusta	Long-billed Spiderhunter	0.0040	0	0.0016	0
Blythipicus rubiginosus	Maroon woodpecker	0.0010	0	0	0.0076
Cacomantis sepulcralis	Rusty-breasted cuckoo	0.0020	0.0060	0	0.0025
Cacomantis sonneratii	Banded bay cuckoo	0	0.0030	0	0.0025
Calorhamphus fuliginosus	Brown barbet	0.0010	0	0	0
Calyptomena viridis	Green broadbill	0.0090	0.0030	0.0221	0
Ceyx erithaca	Black-backed kingfisher	0.0070	0.0119	0.0063	0.0050
Ceyx rufidorsa	Rufous-backed kingfisher	0.0299	0.0627	0.0568	0.1008
Chalcophaps indica	Emerald dove	0.0080	0.0179	0.0284	0.0151
Chloropsis cyanopogon	Lesser green leafbird	0.0010	0	0	0
Chloropsis sonnerati	Greater green leafbird	0.0010	0	0	0
Chrysophlegma mentalis	Checker-throated woodpecker	0	0.0030	0.0016	0

Appendix…continue..

SCIENTIFIC NAME	COMMON NAME	Logged forest		VJR	
		TFR (10 years)	UGFR (30 years)	TFR	UGFR
Chrysophlegma miniaceus	Banded woodpecker	0	0	0.0016	0
Copsychus malabaricus	White-rumpedshama	0.0259	0.0567	0.0331	0.0277
Culicicapa ceylonensis	Grey-headed canary-flycatcher	0.0010	0.0179	0.0110	0.0050
Cymbirhynchus macrorhynchos	Black-and-red broadbill	0.0020		0	0
Cyornis banyumas	Hill blue flycatcher	0.0020	0	0	0
Cyornis concretus	White-tailed flycatcher	0.0010	0	0	0.0025
Cyornis tickelliae	Tickell's blue flycatcher	0	0.0060	0	0.0025
Cyornis unicolor	Pale blue flycatcher	0	0.0090	0.0032	0
Dicaeum cruentatum	Scarlet-backed flowerpecker	0.0010	0.0030	0	0.0025
Dicaeum maculatus	Yellow-breasted Flowerpecker	0.0189	0.0239	0.0174	0.0252
Dicaeum percussus	Crimson-breasted Flowerpecker	0.0110	0.0119	0.0095	0.0227
Dicaeum trigonostigma	Orange-bellied flowerpecker	0.0080	0.0209	0.0079	0.0277
Dicrurus aeneus	Bronzed drongo	0	0	0.0063	0
Dicrurus annectans	Crow-billed drongo	0	0	0	0.0050
Dicrurus paradiseus	Greater Racket-tailed Drongo	0.0010	0	0	0
Dicrurus remifer	Lesser Racket-tailed Drongo	0.0010	0	0	0
Enicurus leschenaulti	White-crowned forktail	0.0040	0.0060	0.0079	0.0025
Enicurus ruficapillus	Chestnut-napedforktail	0.0070	0.0328	0.0174	0.0479
Erpornis zantholeuca	White-bellied erpornis	0	0.0388	0.0063	0.0403
Erythrura prasina	Pin-tailed parrotfinch	0	0	0	0.0025
Eumyias thalassinus	Verditer flycatcher	0	0.0030	0	0.0050
Eurylaimus javanicus	Banded broadbill	0		0.0016	0
Ficedula mugimaki	Mugimaki flycatcher	0.0040	0.0179	0.0142	0.0050
Ficedula westermanni	Little pied flycatcher	0.0040	0	0.0016	0.0025
Ficedula zanthopygia	Yellow-rumped flycatcher	0.0020	0	0	0
Halcyon coromanda	Ruddy kingfisher	0	0	0.0016	0
Harpactes diardii	Diard's trogon	0	0	0	0.0025
Harpactes duvaucelii	Scarlet-rumped trogon	0	0	0.0016	0.0025

Appendix…continue..

SCIENTIFIC NAME	COMMON NAME	Logged forest		VJR	
		TFR (10 years)	UGFR (30 years)	TFR	UGFR
Harpactes orrhophaeus	Cinnamon-rumped trogon	0.0020	0	0	0
Hemixos flavala	Ashy bulbul	0	0.0030	0	0
Hypogramma hypogrammicum	Purple-naped sunbird	0.0199	0.0478	0.0252	0.0302
Hypothymis azurea	Black-naped monarch	0.0080	0.0119	0.0079	0.0025
Iole propinqua	Grey-eyed bulbul	0.0050	0.0030	0	0.0227
Irenna puella	Asian fairy-bluebird	0.0010	0	0.0032	0.0101
Ixos malaccensis	Streaked bulbul	0	0.0030	0.0032	0.0050
Lacedo pulchella	Banded kingfisher	0.0010	0.0090	0.0063	0.0076
Lanius cristatus	Brown shrike	0.0010	0	0	0
Lanius tigrinus	Tiger shrike	0.0020	0.0030	0.0032	0
Leptocoma calcostetha	Copper-throated sunbird	0.0010	0	0	0
Lonchura leucogastra	White-bellied munia	0		0.0016	0
Lonchura leucogastroides	Javanmunia	0.0010		0	0
Luscinia cyane	Siberian blue robin	0.0100	0.0119	0.0110	0.0202
Macronus gularis	Pin-striped Tit babbler	0	0.0239	0	0.0050
Macronus ptilosus	Fluffy-backed tit-babbler	0.0010	0	0	0
Malacocincla malaccencis	Short-tailed babbler	0.0090	0.0119	0.0126	0.0050
Malacocincla sepiaria	Horsefield's Babbler	0.0030	0	0	0
Malacopteron affine	Sooty-capped babbler	0.0040	0	0.0126	0.0151
Malacopteron cinereum	Scaly-crowned babbler	0.0259	0	0.0363	0.0025
Malacopteron magnirostre	Moustached babbler	0.0249	0.0239	0.0205	0.0176
Megalaima mystacophanos	Red-throated barbet	0.0010	0	0	0
Meiglyptes tukki	Buff-necked woodpecker	0.0149	0.0209	0.0047	0.0076
Motacilla flava	Western Yellow wagtail	0	0.0030	0	0
Muscicapa dauurica	Asian brown flycatcher	0	0.0030	0	0
Muscicapa ferruginea	Ferruginous flycatcher	0	0.0030	0	0
Muscicapa muttui	Brown-breasted flycatcher	0	0	0	0.0025
Napotherae pilepidota	Eyebrowed Wren-Babbler	0	0.0030	0	0

Appendix…continue..

SCIENTIFIC NAME	COMMON NAME	Logged forest		VJR	
		TFR (10 years)	UGFR (30 years)	TFR	UGFR
Nisaetus alboniger	Blyth's Hawk-eagle	0.0010	0	0	0
Oriolus xanthonotus	Dark-throated oriole	0	0	0.0016	0
Orthotomus sericeus	Rufous-tailed tailorbird	0.0040	0.0060	0.0047	0
Otus lettia	Collared-scops owl	0	0.0030	0	0
Pellorneum capistratum	Black-capped babbler	0.0020	0.0119	0.0063	0
Philentoma pyrhoptera	Rufous-winged philentoma	0.0209	0.0299	0.0205	0.0151
Phylloscopus borealis	Arctic warbler	0.0010	0.0060	0.0032	0.0151
Phylloscopus emeiensis	Emei leaf-warbler	0	0.0090	0	0.0050
Picus puniceus	Crimson-winged woodpecker	0	0.0030	0	0
Pitta sordida	Hooded pitta	0.0020	0	0	0
Platylophus galericulatus	Crested jay	0.0010	0	0.0016	0
Pomatorhinus montanus	Chestnut-backed Scimitar-Babbler	0	0	0	0.0050
Pycnonotus atriceps	Black-headed bulbul	0.0030	0.0328	0.0032	0.0101
Pycnonotus blanfordi	Streak-eared bulbul	0	0.0060	0	0.0076
Pycnonotus brunneus	Red-eyed bulbul	0.0199	0.0030	0.0016	0.0025
Pycnonotus cyaniventris	Grey-bellied bulbul	0.0040	0.0060	0.0032	0.0076
Pycnonotus erythropthalmos	Spectacled bulbul	0.0139	0.0358	0.0174	0.0277
Pycnonotus finlaysoni	Stripe-throated Bulbul	0.0010	0.0030	0	0
Pycnonotus melanoleucos	Black-and-white bulbul	0.0010	0	0	0
Pycnonotus simplex	Cream-vented Bulbul	0.0030	0	0	0
Pycnonotus squamatus	Scaly-breasted bulbul	0	0.0030	0	0
Rhinomyias brunneata	Brown-chested jungle-flycatcher	0.0060	0	0.0174	0
Rhinomyias umbratilis	Grey-chested jungle-flycatcher	0.0020	0	0	0.0076
Sasia abnormis	Rufouspiculet	0.0110	0.0060	0	0.0151
Serilophus lunatus	Silver-breasted broadbill	0	0.0030	0.0079	0
Stachyridopsis ruficeps	Rufous-capped Babbler	0	0	0.0016	0
Stachyridopsis rufifrons	Rufous-fronted Babbler	0.0020	0	0.0016	0
Stachyris erythroptera	Chestnut-winged Babbler	0.0329	0.0060	0.0205	0

Appendix…continue..

SCIENTIFIC NAME	COMMON NAME	Logged forest		VJR	
		TFR (10 years)	UGFR (30 years)	TFR	UGFR
Stachyris leucotis	White-necked babbler	0	0	0	0.0050
Stachyris maculata	Chestnut-rumped Babbler	0.0030	0	0.0063	0
Stachyris nigriceps	Grey-throated babbler	0.0129	0.0776	0.0142	0.0932
Stachyris nigricollis	Black-throated babbler	0.0040	0	0.0079	0
Stachyris poliocephala	Grey-headed babbler	0.0199	0.0269	0.0237	0.0227
Tephrodornis gularis	Large Woodshrike	0	0	0	0.0076
Terpsiphone paradisi	Asian paradise-flycatcher	0.0040		0.0158	0
Trichastoma bicolor	Ferruginous babbler	0.0010	0	0	0
Trichastoma rostratum	White-chested babbler	0.0010	0	0.0016	0
Tricholestes criniger	Hairy-backed bulbul	0.0299	0.0299	0.0205	0.0630
Zoothera citrina	Orange-headed thrush	0	0.0030	0.0016	0.0101
Zoothera sibirica	Siberian thrush	0	0	0	0.0025