1

INTRODUCTION

1.1 Lowland Tropical Rainforest

The total forested area in Malaysia are approximately 19.42 million ha or 59% of the land area. Of this, there are 5.86, 4.30 and 9.24 million ha are in Peninsular Malaysia, Sabah and Sarawak respectively (FRA 2010). Total forested areas did not include plantation areas such as rubber trees and oil palm plantations. Majority of the forested areas in Malaysia was dominated by Dipterocarp forest (upper, hill and lowland) (89%) followed by peat swamp forest (7%), and mangrove forest (3%) (FRA 2010).

The lowland tropical rainforest is dominated by dipterocarp trees (family dipterocarpaceae) at many sizes (Whitmore 1985; Johns 1996; Edwards et al. 2009). A total of 168 species from 14 genera of dipterocarp tree were recorded in Peninsular Malaysia spreading from the lowland to upper hill (Mori et al. 1990). The common species include *Dryobalanops aromatic, Shorea parvifolia, Neobalanocarpus heimii,* and *Duabanga grandifolia*.

The lowland tropical rainforests constitute the largest terrestrial biome covering almost 20 million squares km with constantly warm and moist climate (Magurran 2007). The forest is also known to be the most complex community with various unique sources of biodiversity when compared to the other forest types (Whitmore 1985). It covers 7% of the Earth's surface but contains more than half of all living species (Huston 1994).

The lowland forest is vertically stratified. Whitmore (1985) defined this stratification into five different layers (A-E); A: the top layer of the tallest and biggest trees mainly dipterocarps which commonly stand as isolated and emerging (>36 m in height), B: upper main canopy with the continuous trees layer mainly dipterocarps and non-dipterocarps (25 to 36 m in height), C: lower main canopy comprises pioneer species mainly *Macaranga* spp. and *Antocephalus chinensis* (15 to 25 m in height), D: upper understorey comprises non-pioneer understorey species mainly non-dipterocarps trees (1.3 to 15 m in height) and E: lower understorey dominated by climbers, shrubs and ferns (0 to 1.3 m in height).

At the understorey level the humidity is high with less light penetration and lower temperature. It is dominated by plants like climbers, epiphytes, strangling plants, parasites and saprophytes (Whitmore 1985).

The tropical rainforests are well known to harbour rich biodiversity and support various wildlife communities (Lambert and Collar 2002; Zakaria et al. 2005). The forest produces more organic material than any other types of biome. Due to higher nutrient availability and complex forest structure, tropical rainforest generates great variety of food resources which are available almost all year round and provide variety of habitats for various kinds of fauna including birds (Manuel and Molles 2005).

Southeast Asia (including Malaysia) is one of the region that supports high number of bird diversity with over 1200 bird species (Sodhi 2002). The forest possesses valuable habitat for many species of bird.

MacArthur and MacArthur (1961) have reported a positive correlation between habitat complexity projected by Foliage Height Diversity (FHD) and bird species richness. The foliage played an important role in bird diversity because many bird select their nesting site based on the foliage density and height above the ground (Welty 1982). MacArthur and Wilson (1967) found that the area with greater volume of vegetation above six meters height is able to support more birds (i.e. warblers) species. The diversity of warblers increased as the complexity of vegetation. Other studies indicated that plant communities with greater foliage height diversity supported more diverse bird communities (MacArthur and MacArthur 1961; Robinson and Holmes 1984; Keane and Morrison 1999).

The natural relationship between forest and birds does exist and they are closely associated with one another. Different niches have separate bird's species in space, time and diets (Whitmore 1985). Based on different space utilization and diets practice by birds inhabiting tropical lowland rainforest, Whitmore (1985) defined five different communities include; 1) above the canopy which occupied by insectivorous and carnivorous birds, 2) upper main canopy dominated by birds feeding largely on fruits, nectar and insect, 3) lower main canopy mainly utilized by insectivorous birds, 4) upper and lower understorey are dominated by insectivorous and birds of various diets taken from the forest floor.

Birds utilize different forest strata or vertical stratifications in order to minimize competition for resources, nesting sites, and territories. Wells (1971) had clearly defined the three groups of bird inhabiting Malaysia lowland rainforest based on different utilization of vertical stratification that exist within the canopy. These group can be divided into 1) top of canopy which includes hornbills, barbets and pigeons which feeding mainly on fruits and insects, 2) middle of the canopy which includes trogons, woodpeckers, and bulbuls, and 3) undergrowth group with pittas, thrushes, babblers, and pheasants.

1.2. Forested Areas in Malaysia

Of the total forested areas in Malaysia, 16.12 million ha are gazetted as protected areas based on the concept of sustainable yield, developed for sustainable forest management. Of these, 14.29 million ha or 74% are gazetted as Permanent Forest Reserve (PFRs) or Permanent Forest Estate (PFEs) and another 1.83 million ha of forest areas outside the PFRs are dedicated as National Parks, wildlife sanctuaries, and nature reserves. Within the PFRs, 3.11 million ha or 22% are designated as protected forest and the remaining 11.8 million ha (78%) are reserved as production forest (FRA 2010).

Approximately 5.86 million ha of forested areas are found in Peninsular Malaysia. Of this 0.39 million ha are the state land, 4.92 million ha are PFRs (2.09 million ha is protected forest and 2.83 million ha is production forest) and the remaining 0.58 million ha are gazetted as the Totally Protected Areas (National Parks and Wildlife Sanctuaries). Of total forested areas inside the PFRs, 93% are dominated by Dipterocarp forest, followed by peat swamp forest (4.9%) and mangrove forest (2%) (Forestry Department 2010).

The establishment of the Totally Protected Areas is specifically for the conservation of biodiversity and environment while the PFRs were established for conservation, protection and production. These establishments considered forest played a vital role in sustaining environmental quality and stability, protecting soil and water, conserving biological diversity, and preserving cultural, recreational and other intrinsic values which enhance people's quality of life (FRA 2010).

1.3. Logging in Peninsular Malaysia

Timber Production Forest (TPF) is one of the twelve components of PFRs that were regulated by respective State Forestry Department. Peninsular Malaysia currently produces timber from TPFs where commercial harvesting of timber on a predetermined rotation cycle is permitted. Bulk of the trees inside the PFRs is the most valuable tree for timber and is mainly comprised of species from the genera of *Shorea, Dipterocarpus, Dryobalanops, Hopea,* and *Parashorea* (Forestry Department 2010).

Currently the PFRs are managed under the Selective Management System (SMS) (Appanah and Weinland 1990; Seng et al. 2004). Previously (in the 1950s to 1970s), Malaysian Uniform System (MUS) was used in Peninsular Malaysia as logging method. This logging method (i.e. MUS) prescribes the removal of the mature crop in a single felling of all trees down to 45 cm DBH (Okuda et al. 2003). However the Selective Management System (SMS) was adopted in Peninsular Malaysia as the most encouraging and complete theoretical system for operational forest management approach by selective removal of the mature crop in a single operation (Seng et al. 2004). It is also to ensure that forest development is biologically, ecologically and environmentally sustainable.

Basically logging was started in 1950's when the technological advances begin to introduce one-man chain-saw as well as with the increasing power and reliability of road-making and log-hauling vehicles, timber extraction become quicker, cheaper, more extensive and intensive (Burgess 1973 in Whitmore 1985).

As a result, Asia has become the region with the highest logging rate, typically twice than those found in other parts of the tropics particularly in the 1970s to 1980s (Peh et al. 2005). Undoubtedly the primary tropical rainforest that are representing by more than three-quarters of all Southeast Asian rainforest are rapidly reducing due to logging activities (Lambert and Collar 2002).

The production of timber in Malaysia was increased approximately three to four-folds between 1965 to 1980s. This primarily triggered by the policies related to regional development areas, industrial estates, and free trade zones with the purpose to promote the wood-based sector pointed by the federal government (Whitmore 1985). Whitmore (1985) reported that in 1977, the logging rate in Malaysia was estimated at the rate of 10 km^2 per day and during 1981 to 1990 deforestation in Malaysia was the highest (average at 1.8% per year) (Peh et al. 2005). As a whole, the Food and Agriculture Organization (FAO) estimated Malaysia's forest loss from 1990 to 1995 is approximately at 400,000 hectares. In 1981 to 1990, an approximate of 73,379 ha (191 m^3/ha) of forested area in Peninsular Malaysia have been logged. This was considered as the highest logging rate so far (FRA 2010).

The tropical rainforest are being exploited for timber particularly at lowland and foothill areas which (below than 1000 m above sea level) due to easy accessibility. This had resulted relatively small remaining of lowland pristine forest in Peninsular Malaysia but leaving the upper hills as intact forest (Lambert et al. 2002; Peh et al. 2005; Nur-Zati et al. 2011).

1.3.1. The Impact of Logging on Birds

"Less than one percent of the tropical rainforests was managed in such a way that harvesting is sustainable" (ITTO 1994).

It is well known that one third of the world bird's species are restricted to tropical forests and at least 70% of resident bird species in South East Asia may be partly or exclusively dependent upon the primary forest (Wells 1985 in Sodhi 2002). Birds and forest are closely tied and interacted between each other (pollination and dispersal). However this intricate web of mutual relationship was disrupted by logging activities which altered the landscape of the original forest structure into logged forest (Barlow et al. 2005).

Forest degradation affects bird species in various ways (Peh et al. 2005). The most pronounce effect of forest degradation is increased in competition for shelter and food resources (e.g. insects and arthropods). Food resources play a major role in influencing bird diversity, abundance, and density in many habitats or places. Food resources provided by the forest are the main attraction to the bird communities. Different pattern of food resources attracted different bird species of which it strongly depending on bird feeding guild and foraging technique.

Logging activities positively reducing the dead wood as the food source for insect and automatically reduce the population of insects in the forest (Styring and Ickes 2001; Dale and Slembe 2005). Most of the old and hollow trees that provide nesting sites for birds were removed by logging activity. Original forest structure with open understorey will be replaced by dense understorey. These badly affect the sallying insectivores, terrestrial insectivores/ground dwelling species (e.g. pheasants, thrushes, pittas and warblers). However species that prefer dense understorey may abundantly increase (Whitmore 1985; Lambert and Collar 1992; Johns 1996; Zakaria et al. 2005; Cleary et al. 2007).

Whitmore (1985) reported that 65% of the forest are destroyed due to logging with majority of the damaged are caused by extraction operation (55%) followed by timber felling (10%) which left only small portion undestroyed (35%). Large emergent trees with crowns of 15 m across will be the best target for the timber (Whitmore 1985). The fallen of these emergent trees will smash up/destroyed considerable amount of lower layers of the forest thus resulted in increases of the amount of edges and gaps. Gap will stimulates the production of flowers and fruits at lower level which attracted more frugivores and nectarivores to forage in the logged forest (Levey 1988; Lambert 1992).

This also will attract more opportunistic species such as bulbuls and spiderhunters to the secondary forest as compared to the primary forest (Wong 1986; Zakaria et al. 2005). These secondary colonizing species has special adaptation to better survive in logged forest such as diet switched from insectivorous to frugivorous. Nevertheless, bird species that are specialized to live in the top of the canopy become less abundant as majority of the canopy were cut off.

Undoubtedly logging activities also may change the physical character of the streams inside the forest, it negatively affect the terrestrial specialist species such as kingfishers and forktails. Fast-flowing streams inside the forest were dammed and formed the stagnant pools thus destroyed the foraging sites for stream-associated species.

Logging activities over time can drastically change bird species composition, distribution and abundance. These activities may destroy bird's specialized microhabitat and sometimes the juveniles or eggs that are still attached to the nest also can be killed. This may resulted in the reduction of population size, species disappearance and biodiversity loss (Huston 1994). Soh et al. (2006) reported that the disturbance due to logging activities in montane/upper hill habitat in Peninsular Malaysia had resulted forest-dependent species to decline when more than 20% of the canopy cover was lost. Eventually, only less than one third of total number of species remains in the area after 40% of the canopy cover was cleared.

Bird distributions pattern are strongly tied with the distribution of their preferred foods. Numerous studies have been conducted on the effects of food supply pattern on Southeast Asia forest birds (e.g. Fodgen 1972; Avery 1980; Wong 1986; Kinnaird et al. 1996; Sodhi 2002). Food availability is influenced by various ecological conditions which further influenced by variation in space and time. Previous study indicate that, food resources provided by recently logged, 30 years-old regenerated and primary forests are varies (Wong 1986; Sodhi 2002; Chazdon 2003; Styring and Zakaria 2004; Peh et al. 2005). This is because different physical characteristics of the forest offer different resources for different bird species.

A study on the effect of food resources (flowers, fruits, and arthropods) on understorey bird communities in two different habitats in Pasoh Forest Reserve (Peninsular Malaysia) indicated that species richness and abundance were higher in primary forest due to high diversity of plant that produced flowers and fruits than in disturbed forest (Wong 1986). Food abundance also influenced population of fig eating Red-knobbed Hornbill (*Aceros cassidix*) in Sulawesi, Indonesia (Sodhi 2002). The population fluctuation was significantly correlated with fig (*Ficus* sp.) fruit biomass where size of bird flock will increased during high biomass of fig-fruit.

1.4. Regenerated Forest

The forest that have been selectively logged will be left after no more valuable trees stand (>30 dbh or 45 dbh) for timber industries are available. This particular forest area will undergoes natural regeneration or rehabilitation.

Naturally regenerated forest is the forest that predominantly composed of trees established through natural regeneration left after been logged from 25 to 60 years (FRA 2010). This forest usually displayed visible indication of human activities and had decreased in term of quality and quantity as original productive forest (FRA 2010).

It is widely known that logging activities distorted the original primary rainforest stand into the downgraded logged-over forest. Kobayashi (2004) reported that five million hectares of tropical rainforest were transformed into secondary degraded, logged-over forest every year. In 2000, 60% of the world's tropical forest was classified as degraded forest (Chazdon 2003). Since 1990's no more primary lowland rainforest was left outside the conservation areas (Whitmore 1985). As predicted by Whitmore (1985), there are no lowland primary rainforest stand (particularly below than 300 m above sea level) existed in Peninsular Malaysia except within the protected areas of Permanent Forest Reserve (PFRs) and National Parks.

Proper conservation action on logged forest is the only way to save this forest and its communities. This can be done through promoting the recovery process of the forest ecosystem to a condition that is closer to unlogged forest although it's time consuming. Regenerated forest which undergone natural recovery process for more than 40 years can act as a good refuge for forest-dependent species and therefore, will enhance species survival (Dunn 2004; Peh at al. 2005; Dent and Wright 2009).

The felling intensity or the number of tree felled per hectare ultimately controlled the degree of forest disturbance. This is related with the logging practices by the loggers/concessionaires (Kobayashi 2004; Seng et al. 2004). This factor governed the success rate of natural regeneration process (Kobayashi 2004).

Rate of the regeneration process also influence by the location of adjacent forest or pocket of unlogged within logged forest. Chazdon (2003) and Dunn (2004) pointed out that the remnant vegetation can attract some dispersal species to deposit seed while perched and thus will promote increases in species richness, tree density and aboveground biomass. They also reported that species richness of several taxa (including bird) increased asymptotically to mature forest level in the first 30 years (Dunn 2004).

Undoubtedly logging activities negatively affected forest physical structure and disturbed the forest-dependent bird communities. However, some species (e.g. opportunistic species like bulbul and spiderhunters) are still benefited from this activity. Most of the big and tall canopy dipterocarps with the minimum diameter of 30 dbh and 36 m height will be the prior target for harvesting. The felling of large trees will directly damage and kill a large portion of remaining stand vegetation. Moreover the improper construction for logging roads and skid trails by the logging concessionaires will further devastate the forest through damaging/altered the soil and water catchments ability (Whitmore 1985).

The physical changes of rainforest structure after logging have been widely documented (Whitmore 1985; Okuda et al. 2003; Dunn 2004; Kobayashi 2004; Seng et al. 2004). The features of the primary forest having well developed canopy trees and sparse ground cover changed to the opening of the canopy thus created big gaps followed by mass growth of predominantly pioneer tree species and creating dense undergrowth (Seng et al. 2004; Dale and Slembe 2005; Cleary et al. 2007).

Secondary logged-over forest generally consists of giant herbs such as bananas, gingers and tangles of big, woody, light demanding climbers/vines whose growth is stimulated by removal of the primary forest canopy. The grows of climber's species in natural regenerating forest will inhibit/retard/delay tree regeneration and growth (Edwards et al. 2009). In general, *Macaranga* sp. is the commonest species in secondary forest which restricted to lowland up 1000 m above sea level. However, *Macaranga* sp. is much less common up to 1000 m above sea level, but the forest is dominated by *Homalanthus* spp. and ferns tree. Forest gaps in secondary logged over forest will promote the development of pioneer species like bamboos and open grasslands dominated by *Imperata cylindrica*.

Persistent exploitation of timber and rapid shrinkage of lowland dipterocarp forest will further enhance biodiversity loss of Southeast Asian birds especially for forest-dependent species (Lambert and Collar 2002). Lindermayer (2002) reported that more than 80% of the world's endangered birds are threatened by habitat loss due to logging activities. Dent and Wright (2009) pointed out that degradation on the old-growth forest potentially lead to the catastrophic species extinction. This had been proved by Ab. Latif et al. where they reported that among 500 species of land birds (including inland species that occupy riparian habitats) inhabiting Peninsular Malaysia, 156 species are endemic to Sundaland, of which 82 species (53%) are now in IUCN red-list.

1.4.1. Birds Studies in Regenerated Forest

Studies of the efficacy of natural regenerated rainforest as surrogate habitat for conserving forest-dependent bird communities in Malaysia are still limited. However numerous studies have been conducted to address the diversity, abundance and richness of bird community assemblages in primary and disturbed forests (Wong 1986; Peh et al. 2005; Zakaria et al. 2005; Cleary et al. 2007). Most of the previous studies on the effects of logging on bird communities in Peninsular Malaysia have focused on early stages of forest regeneration (as reviewed by Peh et al. 2005). Little studies have focused on bird diversity and species assemblages of regenerated forests with more than 20 years of regeneration.

Undeniably the occurrence of bird species is closely concomitant with their preferred food resources. Wong (1986) studied the effect of food availability influenced trophic organization of bird inhabiting primary and 30 years-old regenerated forest in Pasoh Forest Reserve (Peninsular Malaysia). The regenerated forest had lower canopy than virgin forest. She reported that both species richness and abundance were lower in regenerated forest than in primary forest due to higher food (e.g. fruits, flowers and arthropods) were observed in primary than in regenerated forests. However, she concluded that the relative importance of the various foraging guilds did not differ significantly between the forests, recommending similar types of foods with similar proportions were present.

Wong (1985) also discovered that understorey bird in the 30 years-old regenerated forest of Pasoh Forest Reserve did not differ significantly with the adjacent unlogged forest in term of number of juveniles, breeding adults and food occurrence. However, she found that the species richness was lower in regenerated forest than in virgin forest.

Edwards et al. (2009) studied the effects of rehabilitation of logged forest on birds in Ulu Segama Forest Reserve, Borneo. Mist-netting method was applied in three different forest types; 1) unlogged forest, 2) naturally regenerated (undergoes selective logging in 1988 to 1989 or 20 years-old) and 3) rehabilitated forest. They reported that lower species richness and species diversity were recorded in natural regenerated forest compared to unlogged and rehabilitated forests. The study also found lower proportion of insectivores and sallying birds recorded in natural regenerated forest and marked increase in frugivores (mostly are Green winged Pigeon, *Chalcophaps indica* and Green Broadbill, *Calyptomena viridis*).

Peh et al. (2005) conducted an investigation on the occurrence of primary forest species in 30 years' old selectively logged forest and mix-rural habitats located in Johor, Peninsular Malaysia. They reported less primary forest species recorded in regenerated forest. They also detected two species (Grey chested jungle Flycatcher, *Rhinomyias umbratilis* and Grey headed Canary Flycatcher, *Culicapa ceylonensis*) are badly affected by logging activity and absent from one to 12 years-old logged forest as reported by Johns (1986). The study also concluded that the majority of bird assemblages in regenerated forest composed by the second growth species (e.g., Rufescent Prinia, *Prinia rufescens*) and edge species (e.g., Olive winged Bulbul, *Pycnonotus plumosus*). However, most of the ground-dwelling primary forest species are still absent in regenerated forest even though patches of unlogged forest are located nearby. The concluded that ground-dwelling species are most sensitive to disturbance caused by logging activity and had low degree of tolerant to smaller trees and prefer sparse understorey. These species are known to construct their nest at ground level and possibly suffered high nest predation in logged forest due to dense undergrowth. The authors finally concluded that the recovery of primary bird species composition in 30 years-old regenerated forest is still incomplete due to heterogeneity in vegetation structure especially lack of emergent trees.

Woodpeckers also can be used as indicator to measure habitat quality (Styring and Zakaria 2004). This group is closely associated with cavities in large trees, large trunk or standing dead trees for nesting and foraging sites. Corresponding to this, Styring and Ickes (2001) conducted an investigation on woodpecker's assemblages in 40 years-old regenerated forest and unlogged forest in Pasoh Forest Reserve, Peninsular Malaysia. They found eleven species assemblages in regenerated forest, twelve species in virgin forest and 9 overlapped species. Three woodpeckers species (*Meiglyptes tristis, Reinwardtipicus validus* and *Dryocopus javensis*) are commonly found in virgin forest but only one species was commonly found in regenerated forest (*Picus mentalis*).

Yap et al. (2007) conducted a study on the effects of selective logging and food resources on bird species in Johor, Peninsular Malaysia. Bimonthly mist-netting was carried out in 30 years-old regenerated forest and unlogged forest. They found no significant difference in term of understorey-bird abundance, relative richness, breeding and molting occurrence and resources abundance between forests. This finding was consistent with most studies done in Malaysia where most forest-dependent species can survived in logged forests although logging tended to affect bird species composition with respect of feeding guilds, nesting and roosting (Wong 1986; Lambert 1992; Cleary et al. 2007).

Kwok and Corlett (2000) studied bird communities inhabiting secondary regenerated forest (30 to 40 years logged forest) and *Lophostemon confertus* plantation in Hong Kong, China. The study discovered that the forest-associated species such as insectivores and insectivores-frugivores were the common species captured in regenerated forest. This study concluded that more complex vegetation in secondary regenerated forest is the key factor harboring better habitat for forest-associated species. The vegetation complexity displayed by developed canopy and dense understorey can attract common generalist species that rely on fruits produced by vines and shrubs. This study that highlights the 40 year old secondary regenerated forest is capable in providing habitat therefore able to conserve bird species.

1.5. Understorey Bird Assemblages in Peninsular Malaysia

Of total 742 bird species recorded in Malaysia, 656 (15 species have been recently added to list in 2005 until 2009) species can be found in various habitats in Peninsular Malaysia (Jeyarajasingam and Pearson 1999; Robson 2000; MNS 2005: MNS 2010). Of these, 445 species are resident, 40 species with both resident and migrant populations, and 243 migrant or vagrant birds (Wells and Medway 1976; MNS 2005; MNS 2010). Of total bird species inhabiting Peninsular Malaysia, 33.6% (221 species or 32 families) confined to aquatic and open habitats. The remaining 66.3% (435 species or 55 families) are associated or confined to forest habitat or known as a forest dependent species (MNS 2005; MNS 2010). One hundred and twenty-three (123) species are considered threatened in Peninsular Malaysia while eight species are considered extinct with no records in the wild for the last 50 years (MNS 2010).

Malaysia has important populations of threatened rainforest bird. Four species are endemic to Thai-Malay Peninsula and from this, three species are confined to Peninsular Malaysia. These are Mountain Peacock-pheasant (*Polyplectron inopinatum*), Malayan Whistling-thrush (*Myophonus robinsoni*), and the lowland Malaysian Peacock-pheasant (*Polyplectron malacence)* (MNS 2005; Birdlife International 2008). Peninsular Malaysia also harbored several vulnerable species such as Blue-banded Kingfisher (*Alcedo euryzona*), Brown chested Jungle Flycatcher (*Rhinomyias* *brunneata*), Short-toed Coucal (*Centropus rectunguis*), and Straw headed Bulbul (*Pycnonotus zeylanicus*) (MNS 2005; Birdlife International 2008).

Different forest vertical stratification provides different niche pattern. Various species of bird exploited different forest space (vertical stratification). This closely associated with their type of feeding and foraging technique (Wong 1986; Laiolo 2002). Species that are commonly utilize the ground and lower storey includes Green-winged Pigeon (*Chalcophaps indica*), Black and Red Broadbill (*Cymbirhynchus macrorhynchos*), Black backed Kingfisher (*Ceyx erithaca*), White rumped Shama (*Copsychus malabaricus*) and several species of bulbuls (family Pycnonotidae) and babblers (family Timalidae) such as Striped-throated Bulbul (*Pycnonotus finlaysoni*), Olive-winged Bulbul (*Pycnonotus plumosus*), Grey-cheeked Bulbul (*Alophoixus bres*), Yellow-bellied Bulbul (*Alophoixus phaeocephalus*), Short-tailed Babbler (*Malacocincla malaccensis*), Horsfield's Babbler (*Malacocincla sepiaria*) and Moustached Babbler (*Malacopteron magnirostre*).

Birds presence at middle to upper storey include Drongo Cuckoo (*Surniculus lugubris*), Chestnut-breasted Malkoha (*Phaenicophaeus curvirostris*), Crimson-winged Woodpecker (*Picus puniceus*), Banded Broadbill (*Eurylaimus javanicus*), and Green Broadbill (*Calyptomena viridis*), and some bulbuls and flycatchers (family Muscicapidae) species (Bransbury 1993; Robson 2000; MNS 2005; MNS 2010). A total of 435 bird species representing 55 families inhabiting Peninsular Malaysia lowland dipterocarp forest utilized different strata of understorey forest and therefore are considered as understorey bird.

2

OBJECTIVES

2.1. Importance

As resources and time for biodiversity conservation are limited, indicator group for overall species richness may represent a useful and rapid method for assessing biodiversity (Lawton et al. 1998; Hughes and Ehrlich 2002; Schulze et al. 2004). The understorey forest-dependent species is the best indicator for assessing the status of local ecological condition due to its high sensitivity to the environment changes (Zakaria et al. 2005; Bottoni 2006; Padoa-Schioppa et al. 2006). Understorey species respond to immediate changes that either directly or indirectly affect their population and distribution in local or regional habitats. As proposed in the basic sciences, the form and function of organisms are closely tied to the environments in which they live (Karr 1976; Ambule and Temple 1983; Stutchbury and Morton 2001; Manuel and Molles 2005).

It is very useful to develop conservation strategy to manage current and future biodiversity. It is important to study the community of birds in the regenerated forest since these birds are reflecting their environment. This info are useful for conserving and upgrading the regenerated forest to the original structure and increase biodiversity composition after been disrupted or diminished in quality and quantity.

Since degradation of primary forests is uncontrolled and still occurring at alarming rate, researchers have suggested that the management of degraded habitat (secondary growth) need to be properly addressed. Little is known about bird community that inhabits regenerated forests (due to logging activity) that experiencing disturbance for more than 20 years. Therefore, information regarding the ability of these regenerated forests in providing habitat to forest birds is inadequate.

To fulfill this aim, understory resident bird inhabiting 30 and 50 years-old of selectively regenerated logged forests were assessed.

Thus, the objectives of this study to;

1. record the species diversity and community structure of understorey bird inhabiting both forests.
2. record and compare bird species composition in term of trophic guild structure within and between both forests.

3

STUDY AREAS

Two study sites were selected for the purpose of this study;

1) A 50 years-old regenerated lowland forest in Ulu Gombak Forest Reserve in Selangor.
2) A 30 years-old regenerated lowland forest in Kenaboi Forest Reserve, Jelebu Negeri Sembilan.

The 30 years-old regenerated forest is also considered as recently disturbed than the 50 years-old regenerated forest. Both study sites are situated in western part of the Peninsular Malaysia (see Figure 3.0-1).

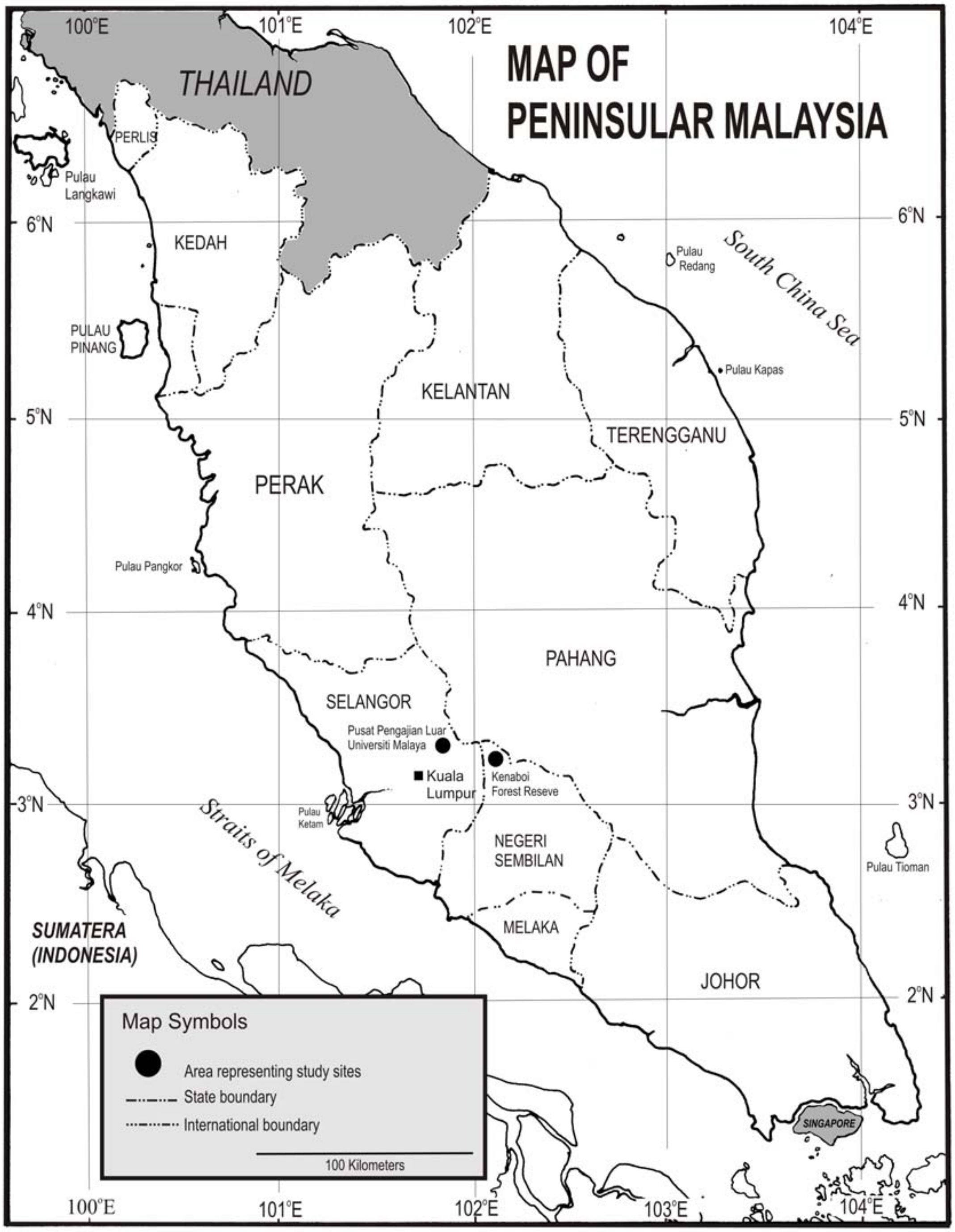


Figure 3.0-1: Location of study areas in Peninsular Malaysia

3.1. The 50 years-old regenerated forest

3.1.1. General

This study area is located in Ulu Gombak Forest Reserve (central coordinates 101º 49'E 3º 11'N) in Selangor state and neighboring with Kenaboi FR in Negeri Sembilan on southern part, Gunung Bunga Buah and Janda Baik Forests in Pahang on western and northern sides (Figure 3.0-1).

The forest has been selectively logged under Malaysian Uniform System (MUS) in 1950 to 1960s but the information on the selectively size logged trees was not available. The forest reserve covered an area of approximately 46,498 hectares (Forestry Department of Selangor, pers. comm.) which consists of various forest habitat ranging from lowland to montane forest of the main range (Hashim et al. 2001; Forestry Department 2008). The study was conducted in the lowland forest with altitude ranges from 150 to 300 m above sea level. The reserve comprises of several tall and big trees from the genera *Shorea* sp., *Dipterocarpus* sp. and *Anisopthera* sp. (Hashim et al. 2001). The area features gaps and patches of secondary growth vegetation such as *Macaranga* sp, bamboo, wild banana, gingers, climbers' plant and lalang (*Imperata cylindrica*). Most of the areas located below 150 m above sea level have been developed for human settlements, plantation and orchard.

The forest is mostly steep hillside and narrow valley bottoms which lies on granite and limestone overlaid by Quarternary alluvium and is covered in red-yellow ultisol soil. Sungai Gombak is the main river that tranverses the northern part of the forest with tributaries such as Sungai Rumput, Sungai Pisang, Sungai Gapis, and Sungai Tiang. On southern side, tributaries of Sungai Klang consist of small rivers such as Sungai Seleh, Sungai Pemulas and Sungai Songlai flowing into Klang Gates reservoir. The average annual rainfall is about 50 mm per week with heavier rain in November and December (208.7 mm). The reserve experienced dry season between January to February. The annual mean temperature average is about 30-32ºC (Forestry Department Peninsular Malaysia 2000).

3.1.2. Record of Protection status

Ulu Gombak Forest Reserve was gazetted as a Wildlife Sanctuary in 1936 (Birdlife International, 2008) without proper definition of its boundaries. More recently, the forest reserve was proposed to be part of the Selangor State Park (total area covers more than 110, 000 ha), which also consist of other 23 forest reserves. Although it has been identified as an environmentally sensitive area, development for the purpose of recreation, research and ecotourism is permitted. The Ulu Gombak Forest Reserve is classified by IUCN as protected area (IUCN 2010).

3.1.3. Threats and conservation issues

Located close to Genting Highland Resort, Ulu Gombak FR is constantly exposed to threat due to possible of high density development to fulfill resort popularity as an amusement and entertainment center. The forest reserve was divided by the Karak Highway, which connects the central region of the peninsula to the eastern side. The Ulu Gombak FR facing greatest threat from the existing and future developments, illegal settlement and agriculture. This will further fragment the area. Furthermore poaching has been reported as one of the potential threat that could cause extinction and biodiversity loss due to the easy access into the forest reserve (Selangor Forestry Department 2000).

3.1.4. Previous studies

The bird fauna of Ulu Gombak FR have been well documented since 1960s in Wells and Medway (1976). The Ulu Gombak Forest Reserve is one of the best sites for bird watching activity (Bransbury, 1993). Previous studies had recorded more than 150 species of birds present d in Ulu Gombak Forest Reserve (Bransbury 1993; Davidson and Chew 2003).

3.2. The 30 years-old regenerated forest (recently disturbed)

3.2.1. General

This study area is located in Kenaboi Forest Reserve in the district of Jelebu at the northwestern part of Negeri Sembilan's state, bordering the state of Pahang in north and Selangor in west (Figure 3.0-1). The forest had been selectively logged under Malaysian Uniform System (MUS) from 1970 to 1980 which covers an area of approximately 46,498 hectares (Forestry Department of Negeri Sembilan, pers.comm.). The study was conducted in the lowland forest with altitude ranging from 100 to 300 m above sea level. The area comprised of patches of some lightly disturbed areas in both upper and lower parts of the forest. The ground vegetation were mainly patches of secondary growth, gaps, shrubs some clumps of giant bamboo and lalang (*Imperata cynlindrica*).

Topographically the area is covered by hilly and lowland areas and lies on the granite and quaternary alluvium which is recorded as the oldest rocks composed mainly phyllite, schist and minor amphibolites and serpentinite (Ghani et al. 2009). The area is irrigated by the Kenaboi River and its tributaries such as Damar, Jemeloi, Kemalai, Kering and Semong.

Some parts of the reserve have been planted with cash crop (i.e. corns, bananas and durians) owned by the local communities or indigenous people. Water quality survey on Kenaboi River recorded that the water body was in Class II based on the interim water quality standard of the Department of Environment, Malaysia (Othman et al. 2007).

3.2.2. Record of Protection Status

Kenaboi Forest Reserve was not listed as one of the potential protected bird area by Birdlife International. The area was not well documented for its flora and fauna until this study was carried out. Preliminary study had recorded several nearly-threatened (NT) and vulnerable (VU) birds' species in the area (Ramli et al. 2009). Nearly-threatened or 'rare' species include Black-Magpie (*Platysmurus leocopterus*), Black-bellied Malkoha (*Phaenicophaeus diardii*), Chestnut-bellied Malkoha (*P. sumatranus*), White-crowned Hornbill (*Berenicornis comatus*), Sooty-capped Babbler (*Malacopteron affine*), Rufous-crowned Babbler (*M. magnum*), Scaly-breasted Bulbul (*Pycnonotus squamatus*), Grey-bellied Bulbul (*P. cyaniventris*), Streaked Bulbul (*Hypsipetes criniger*) and Lesser-green Leafbird (*Chlolopsis cyanopogon*). The vulnerable (VU) species was Blue-banded Kingfisher (*Alcedo euryzona*).

3.2.3. *Threats and conservation issues*

The biodiversity of Kenaboi FR biodiversity are threatened by poaching due to the easy access. In addition, the total area of the forest reserve is slowly decreasing resulted from illegal agriculture activity and the establishment of human settlements.

3.2.4. Previous studies

Record on biodiversity including avifaunas of Kenaboi FR is not properly documented. Previous study has recorded 152 bird species inhabiting the forest reserve. Of this, 31 nearly threatened species and two vulnerable species (i.e. Brown-chested Jungle Flycatcher, *Rhinomyias brunneata* and Blue-banded Kingfisher, *Alcedo euryzona*) were recorded (Ramli et al. 2009).

4

MATERIALS AND METHODS

4.1 Methods

4.1.1. Data collection

The study was conducted from January to December 2007. There are a total of twelve sampling sites in each study area. During each visit, twenty mist-nets were erected to sample understorey bird. Mist-netting technique was used to census understorey bird because it provides efficient and reliable way to document diversity of understorey birds inhabiting the tropical forest (Derlindati and Caziani 2005). Although some birds can be identified via observation, the approach only provides limited data (Bibby et. al. 1998). Captured birds provide details for affirmative identification, morphometric measurement, specimens for museum, blood extraction or other tissues for genetic study, parasitological study and to determine the breeding and moulting status of the birds (Rahman 2002). Another advantage of using mist-net is that it is more robust to differences in researchers' ability to identify bird species when compared to direct observation technique. Since it is expected that the nets are covering the heights at which understorey birds spent most of their time on daily activity (Blendiger 2005), captures can serve as indicator for relative bird abundance for each species between samples.

However, Peh et al. (2005) reported mist-netting in logged forest failed to record any of the cryptic and ground-dwelling species. Bibby et al. (2000) and Peh et al. (2005) suggested that the observation method is more time efficient and enables to detect larger proportion of avifauna than other methods. Yet this method tends to underestimate richness and abundance of cryptic species.

Twenty mist-nets with the dimension of twelve metres long, 2.7 m high, with mesh size of 36 mm and four shelves were set up randomly (at least 10 metres apart from each other). Since both study areas are heterogeneous in habitat, this method was applied at 12 sampling stations within the 30 years-old and 50 years-old regenerated forests. Previous study discovered that more birds will be caught if the nets were set-up along lines across moderately dense vegetation or open areas with little understorey vegetation (Rahman 2002).

The nets were set 0.5 m above the ground to avoid ground predator such as snakes, ants, and monitor lizard. The nets were supported by two aluminum poles and strengthen by rafia/plastic strings. The nets were operated for 11 hours (if weather permitted) for three consecutive days. Netting for more than three days in the same area is not advisable since it will lead to a drastic reduction in the numbers of captures and increases in the number of recapture (Wilson and Moriarty 1976; Rahman 2002).

The nets were operated from 0700 hours until 1800 hours but were closed in the event of heavy rain or strong winds. The nets were inspected every hour to extract captured birds. This will minimize mortality due to ground predators and pressure from heat, cold and thirst. Small birds with total body length less than 11 cm can easily die if caught in the nets for more than one hour (personal observation). Beside their high metabolic rate, small birds can easily fit through the mesh and get seriously tangled.

Birds caught in the nets were removed and placed in the cloth bags. Morphological measurements such as tarsus length (mm), bill length/culmen (mm), bill height (mm), bill width (mm), gape (mm), wing length (cm), tail length (cm), keel (mm) and total body length (cm) were obtained using calipers (0.1 mm) and steel ruler (0.1 cm). In addition sexes were also recorded. The bird body weight (g) was measured using Pesola® spring balance (100g or 600g) (McCracken et al. 1998). These morphological measurements can be used in assisting identification.

All captured birds except kingfishers were ringed with serial number on their tarsus before been released. Therefore, recaptured individuals can be identified and excluded from total capture. Bird ringing has role in providing information on migration, population demography, ecology, behavior and life history (McCraken et. al. 1998). Ringing data assist in determining migration route, stopover sites, breeding ranges, and wintering ranges of birds and also widely used to estimate population size and population turnover through mark-recapture studies. Ringing facilitate behavioral studies especially on breeding and wintering territories, mate selection, dispersal distances, daily movement patterns, resource partitioning and diet. The advantage of ringing system is that the population size can be accurately estimated from capture-recapture data.

Species were identified using Jeyarajasingam and Pearson (1999), Robson (2000) and Wells (1999; 2006). The bird species were classified according to their distribution and occurrence status and feeding modes as suggested by Briffet (1986), Jeyarajasingam and Pearson (1999) and MNS (2005; 2010).

4.2. Data Analysis

4.2.1. Capture Rate

To effectively estimate species richness within and between study sites, this study used capture rate (number of bird captured per 100 netting hours) as the measure of bird relative abundance.

$$\textbf{Capture rate (C)} = \frac{\textbf{Total individual capture per month (N)}}{\textbf{Netting hours (X)}}$$

This will account for differences in netting hours (mist-netting effort) sites. The degree of dominant per sample was expressed as the ratio between average numbers per capture in 100 netting hours of the most abundant species and average number of all birds captured in 100 netting hours. Capture rate was used to minimize the biases in sampling approach and to provide the most accurate data for both sites. Capture rate regulates the function of time over effort spent for mist-netting with the number of species successfully captured during each visit.

Netting hours can be represented by this formula:

$$\mathbf{X = (a) \times (b) \times (c)}$$

Where, X = Netting hours at one sampling station, a = total mist-nets erected in each station (e.g. a = 20 mist-nets), b = number of sampling day (e.g. b = 3 days), c = total hours of mist-net operation (ranges from one hour to twelve hours a day).

4.2.1. Species Diversity and Richness

Conservation assessment required the measure of species diversity (Bailey 1995). Diversity measures require an estimate of species importance in the community (Krebs 1999). In this case, Shannon-Weiner is the most widely used index (Fowler et al. 1998). Species diversity is defined as the number of species (richness) and their evenness (equitability) as their components (Gibbs et. al. 1998). If species are unevenly abundant, community diversity is lower than when they are equally abundant. Adding species to the community increases the diversity. The two components, richness and evenness can be computed separately.

To analyse the diversity and abundance of bird assemblages between and within study sites, this study estimated species diversity, richness and evenness using several indices such as Shannon-Weiner, Simpson D, Berger-Parker Dominance, Simpson evenness and pooled rarefaction based on the number of captures for each species. Migratory birds that were captured in this study will be excluded in all analyses.

The main assumption of the Shannon-Weiner index is that the sample is randomly distributed. Shannon-Weiner has moderate capacity to discriminate between communities and is mainly influenced by abundances of the medium abundant species (Magurran 2003). On the other hand, the Simpson index is very sensitive to the abundance of the most common species. It gives the probability of any two individuals drawn at random from a finite community belonging to different species.

Evenness is closely tied with the species diversity and indicates equality of the populations numerically. The evenness value of a population is ranges from 0 to 1. Population that has less variation between species will has higher evenness value. Species richness simply refers to the number of species in the community. Ludwig and Reynolds (1988) suggested Margalef index for measuring species richness.

To estimates species richness and sampling efficiency for both study sites, three common nonparametric estimators were used from Species Diversity and Richness Ver. 4 (Seaby and Henderson 2006). The Chao 1, Chao 2 and MMMeans were highly recommended by Herzog et al. (2002) due to the least biased and high accurately. The MMMeans was based on the Michaelis-Menten model and it is more sensitive to differences in community structure than most other estimators. The Chao 2 basically was based on the presence and absence of the species and it is more sensitive to sample size. The Chao 1 is the abundance-based estimators and practically has an advantage over all other estimators: it can be employed to the raw data without the time consuming subdivision of observation into species lists (Herzog et al. 2002). Sampling efficiency was calculated by dividing the actual species number caught by the number of estimated species (Brühl 2001).

To determine the adequacy and completeness of the sampling between both study sites, randomized species accumulation curves (with 100 randomized runs) were conducted. The study also used sample-based rarefaction curve with 95% confidence intervals, constructed in Species Richness and Diversity Ver. 4 to compare pattern of species richness within 12 sampling stations in both study sites. Non-parametric Mann-Whitney U Test was used to compare the mean between the two communities and checked communities differences between the study sites.

Descriptive statistics was frequently used to present the information on species distribution. Descriptive statistics was used to calculate central tendency (i.e. mean), to measure the variability of distribution size (largest and smallest value in the distribution), and to measure the stability provided by the standard error (where the small value indicates a greater stability or small sampling error).

The normal distribution test was carried out using Kolmogorov-Smirnoff test to determine whether the bird community assemblages in both study sites are normally distributed. A normal distribution is demonstrated by $p>0.05$ and the analysis of kurtosis and skewness indicated the value that approaching zero. The p value which less than 0.05 indicated that the community was not distributed normally (Magurran 2003).

This study chooses an observed frequency distribution or a species rank abundance to summarize the data of captured understorey bird. This is mainly due to the large collection of individuals that represent many species that have unequal representative. Some species were represented by only a single individual whereas few species were represented by more individuals (sometimes up to 80 individuals).

Independent Chi-square test was applied to test significantly different ($p<0.05$) of bird species assemblages with respect to species composition and relative abundance between the two different regenerated forests.

Cluster analysis based on Jaccard Coefficients was used to compare the percentage of similarity in species composition between and within the study sites. This analysis measure the similarity in species composition based on binary data (species presence = 1 and species absence = 0). Similarity percentage was calculated by dividing the total number of shared species by the total number of shared plus unshared species. Unweighted Pair Group Method with Arithmetic mean (UPGMA) was used as the clustering method which averages are weighted by the number of taxa in each cluster at each step. As a result, each distance contributes equally to the final result.

In this study, the forest was divided into four zones, i.e. canopy level, middle level, lower level and ground level (Bransbury 1993). All capture species are assumed to utilize at least one of those forest levels.

4.2.3. Trophic Guild Structure

This study assigned bird's species to 14 feeding guilds with respect to the type of food consumed and foraging technique. The study also divided species into separate foraging and feeding guilds. Foraging guild was classified into four types, i.e. arboreal foragers, sallying foragers, undergrowth foragers and generalist (include more than one foraging technique). Feeding guild was divided into five types which include insectivores, frugivores, seed, carnivores and generalist (diet includes two or more food sources (Edwards et al. 2009).

The study also used independent chi-square test to determine whether species assemblages with respect to foraging and feeding guild differed significantly between study sites. Mean proportion (number of individual per species) were used to compare the species assemblages with respect to foraging and feeding guilds between study sites.

All diversity and statistical analyses were computed using SPSS Statistics 17.0 and Species Diversity and Richness program Ver. 4 (Seaby and Henderson 2006), data analysis toolpax constructed in Microsoft Excel 2010 and Multi Variate Statistical Package (MVSP) version 3.1.

5

RESULTS

5.1 Bird Diversity in 30 and 50 years-old Regenerated Forests

5.1.1. Overall

One thousand four hundred and eighty two (1482) individuals (recaptured individuals were excluded) belong to 120 species and 26 families were captured. A total of 12 species (five families) of migratory bird were excluded in this study.

Remaining 108 species from 24 families belong to the resident species. Of these, 54 species (50%) were caught only in 30 years-old regenerated forest and 8 species (7.4%) were captured only in 50 years-old regenerated forest. Another 46 species (42.5%) were trapped in both study sites.

The family Pycnonotidae have the most number of species captured (18 species) and followed by family Timalidae (14 species) (Table 5.1-1).

Little Spiderhunter, *Arachnothera longirostra* was the most frequently species caught (represented by 212 individuals; 17.8 ± 16.34) (Table 5.1-2). These species was commonly captured in all sampling stations (180 individuals were captured in 30 years-old regenerated forest and 32 individuals were trapped in 50 years-old regenerated forest) (Table 5.1-2).

Table 5.1-1: The species richness and abundance recorded in the 30 years-old and the 50 years-old regenerated forest in Peninsular Malaysia in 2007 (listed by family).

Family	30 years-old		50 years-old		Total	
	Species	Individuals	Species	Individuals	Species	Individuals
Pycnonotidae	17	209	10	68	18	277
Timalidae	14	231	7	49	14	280
Muscicapidae	8	30	4	20	9	50
Sylviidae	8	47	3	15	8	62
Picidae	8	26	4	11	8	37
Nectariniidae	7	250	6	68	9	318
Alcedinidae	4	38	4	9	5	47
Turdidae	3	46	3	18	4	64
Cuculidae	4	11	2	3	4	14
Monarchidae	3	36	2	6	3	42
Eurylaimidae	4	11	2	3	5	14
Dicaeidae	3	66	4	103	4	169
Estrildidae	3	7	1	1	3	8
Trogonidae	3	4	-	-	3	4
Zosteropidae	2	6	-	-	2	6
Columbidae	1	12	1	5	1	17
Irenidae	1	3	-	-	1	3
Rhipiduridae	1	3	-	-	1	3
Chloropseidae	1	2	-	-	1	2
Corvidae	1	1	-	-	1	1
Apopidae	1	1	-	-	1	1
Meropidae	1	1	1	1	1	2
Oriolidae	1	1	-	-	1	1
Capitonidae	1	1	-	-	1	1
Total	100	1043	54	380	108	1423

The second most abundant species was Orange-bellied Flowerpecker (*Dicaeum trigonostigma*) represented by 96 individuals (mean abundance ± SD; 8.0 ± 12.7). Other species were represented by less than 70 birds (Table 5.1-2).

Eleven singleton species were caught in both study sites and classified as rare due to only one individual were captured throughout study period (12 samplings). These species were represented by a group of several species such as broadbills, trogons, woodpeckers, flycatcher, kingfisher and spiderhunter (Table 5.1-3).

Most of the species captured in this study represented by only one or two individuals and were classified as rare species (25 species were represented by a single individual while 18 species were represented by two individuals). Of singleton species captured, 26 species were caught in the 30 years-old regenerated forest and 18 species were captured in the 50 years-old regenerated forest. Only one species that represented by more than 200 individuals was captured (Figure 5.1-1).

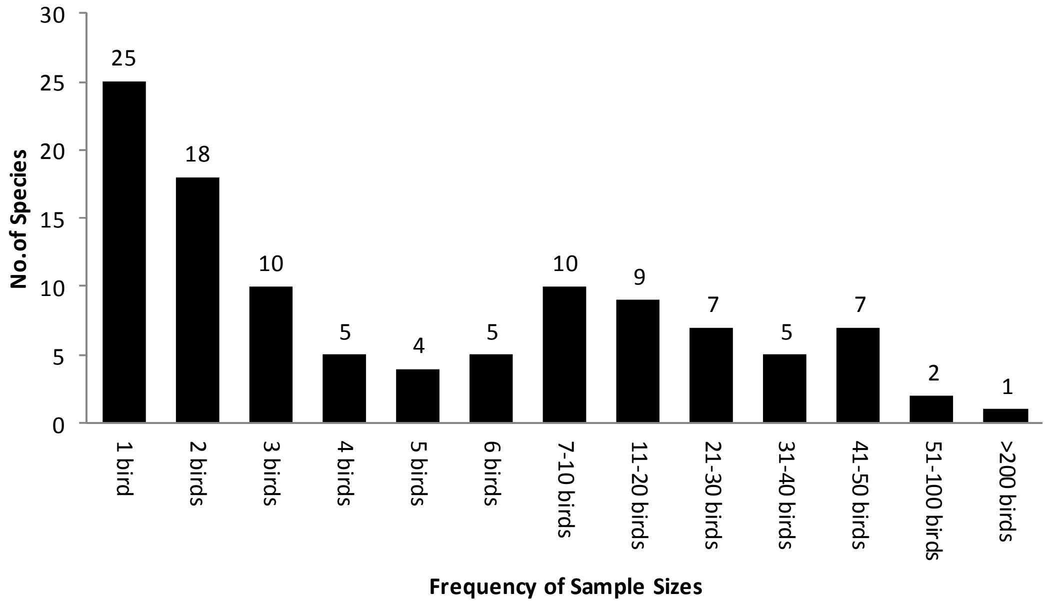


Figure 5.1-1: Cumulative frequency of 24 sample sizes that represents species recorded from two study areas.

Table 5.1-2: Several most abundant species (*total bird from both study areas)

No	Species	*Capture frequency	Mean ± SD
1	Little Spiderhunter, *Arachnothera longirostra*	212 birds	17.80 ± 16.34
2	Orange-bellied Flowerpecker, *Dicaeum trigonostigma*	96 birds	8.00 ± 12.70
3	Black headed Bulbul, *Pycnonotus atriceps*	67 birds	5.58 ± 8.10
4	Striped-tit Babbler, *Macronous gularis*	50 birds	4.17 ± 5.51
5	Grey-headed Babbler, *Stachyris poliocephala*	49 birds	4.08 ± 3.23
6	Grey-throated Babbler, *Stachyris nigriceps*	48 birds	4.00 ± 6.10
7	Short-tailed Babbler, *Malacocincla malaccensis*	46 birds	3.83 ± 4.71

Table 5.1-3: List of several singletons species caught in the study areas.

No.	Species	*Status of Protection
1	Black and Red Broadbill, *Cymbirhynchus macrorhynchos*	TP
2	Black and Yellow Broadbill, *Eurylaimus ochromalus*	TP and NT
3	Banded Broadbill, *Eurylaimus javanicus*	TP
4	Chequer-throated Woodpecker, *Picus mentalis*	TP
5	Cinnamon-rumped Trogon, *Harpactes orrhophaeus*	TP
6	Japanese-paradise Flycatcher, *Tersiphone atrocaudata*	TP and NT
7	Orange-backed Woodpecker, *Reinwardtipicus validus*	TP
8	Rufous-collared Kingfisher, *Actenoides concretus*	TP and NT
9	Scarlet-rumped Trogon, *Harpactes duvaucelli*	TP
10	Silver-breasted Broadbill, *Serilophus lunatus*	TP
11	Thick-billed Spiderhunter, *Arachnothera crassirostris*	TP

*Status of protection by IUCN 2010.

5.1.2. Bird Capture Per Site

The mist-netting result shows that the 30 years-old regenerated forest harbours 24 bird families and 100 species (1043 individuals) during 6,480 mist-netting hours. While the 50 years-old regenerated forest harbours 15 families (62%) representing 54 species (380 individuals) in 4,540 hours of netting operation (Table 5.1-4).

The total capture rate was higher in the 30 years-old regenerated forest (1.72 individuals per hour) while total capture rate in the 50 years-old regenerated forest was only 0.89 individuals per hour (Table 5.1-4).

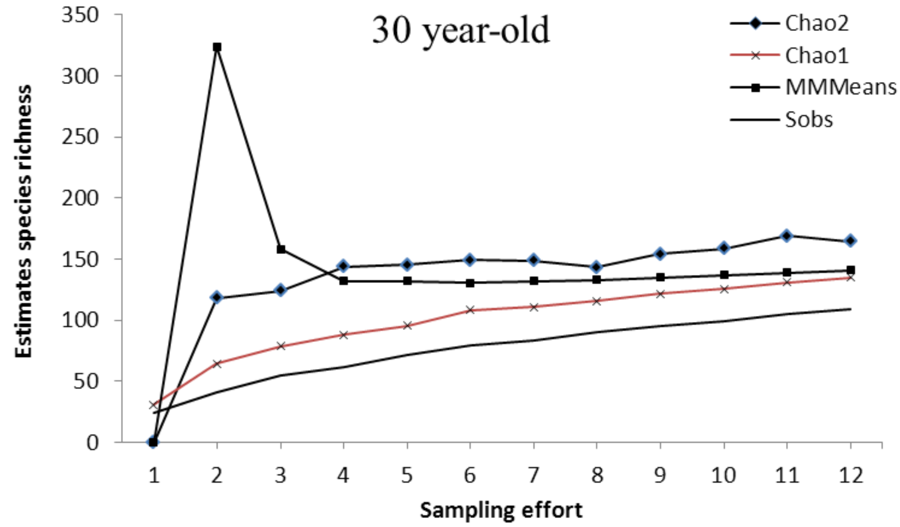
Table 5.1-4: Capture success, number of captured species and individuals in the 30 and the 50 years-old regenerated forest. N = captured species, I = captured individuals, H = Netting hours and I/H = captured rate per hour.

Sampling station	30 year-old regenerated forest				50 year-old regenerated forest			
	N	I	H	I/H	N	I	H	I/H
1	6	13	240	0.05	3	6	140	0.04
2	15	27	380	0.09	10	12	300	0.04
3	34	82	580	0.14	15	29	540	0.05
4	32	90	620	0.15	25	93	480	0.19
5	50	254	620	0.41	24	110	620	0.18
6	45	220	620	0.35	20	53	380	0.14
7	41	121	620	0.12	13	21	200	0.11
8	30	129	600	0.22	2	3	200	0.02
9	18	39	620	0.06	15	23	680	0.03
10	10	19	620	0.03	12	18	340	0.05
11	12	33	460	0.07	8	12	300	0.04
12	10	16	500	0.03	0	0	360	0.00
Total	100	1043	6480	1.72	54	380	4540	0.89

Estimated total species richness for 30 years-old regenerated forest ranges between 100.6 and 141.2, which resulted in more than 75% sampling efficiency. However estimated total species richness in 50 years-old regenerated forest ranges between 70.5 and 119 which presented more than 50% sampling efficiency (Table 5.1-5 and Figure 5.1-2).

Table 5.1-5: Species richness estimation by nonparametric for 30 and 50 years-old regenerated forests. Numbers in parentheses indicate sampling efficiency. MMMeans refer to Michaelis-Menten.

Richness Estimators	30 years-old	50 years-old
	Value	Value
Actual number of species	100.0	54.0
Chao 1	100.6 ± 10.2 (108.3)	70.5 ± 12.0 (87.9)
Chao 2	135.1 ± 17.9 (80.7)	81.9 ± 22.5 (75.7)
MMMeans	141.2 ± 70.2 (77.2)	119.0 ± 43.0 (52.1)



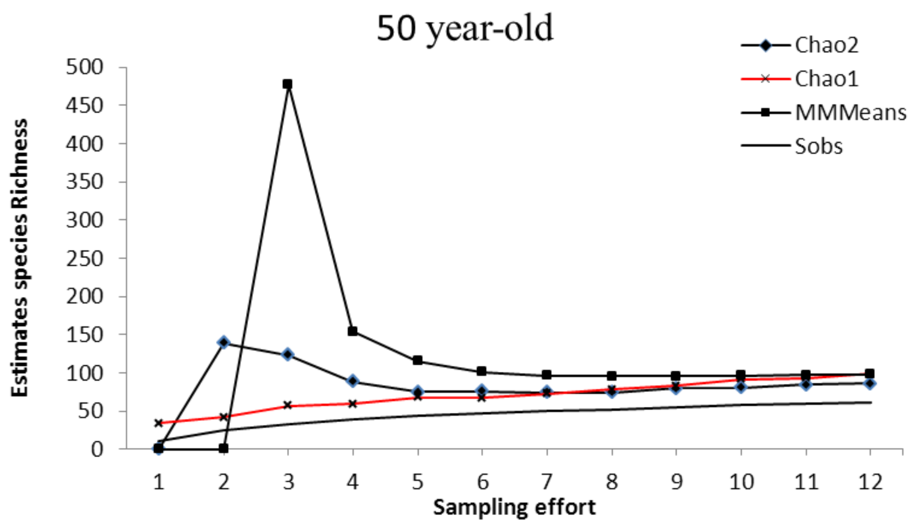


Figure 5.1-2: Non-parametric estimator's curve per sampling effort for 30 and 50 years-old regenerated forests. S_{obs} refer to the actual number of species accumulation.

Species accumulation curve for bird sampling begin to approach asymptotes after all 12 stations were sampled. These indicated that the sampling effort has reached sufficient intensity where the sampling had succeeded in capturing most of the species present in both study areas (of the resident species have been recorded).

Both accumulation curves have shown initial increase in species number before gradually declines (Figure 5.1-3). In both areas, the rate of acquisition of new species had greatly decreased with effort (area or time sampled). At twelve samplings, both study areas nearly reached static level of species composition. The species accumulation curve increase slowly after the sixth samplings. This increasing pattern was highly contributed by migratory species present in the area. Therefore, sampling for resident species in both study areas is assumed comprehensive. Magurran (2007) stated that if the diversity curve reaches an asymptote, the user can be reasonably confident that the diversity of assemblages as measured by the index has been encapsulated.

Newly added species for each sampling is different between both study sites. The 30 years-old regenerated forest had higher value of newly added species. Both study areas show similar pattern of accumulation curve after reaching some point. Both areas have less newly added species after seven sampling. The newly added species become significantly lower with less than four newly added species after ten sampling was carried out.

This result is in line with MacArthur and Wilson (1967) and Cody (1985) that had shown larger area requires more samplings since it harbours more species than smaller area which harbors less species.

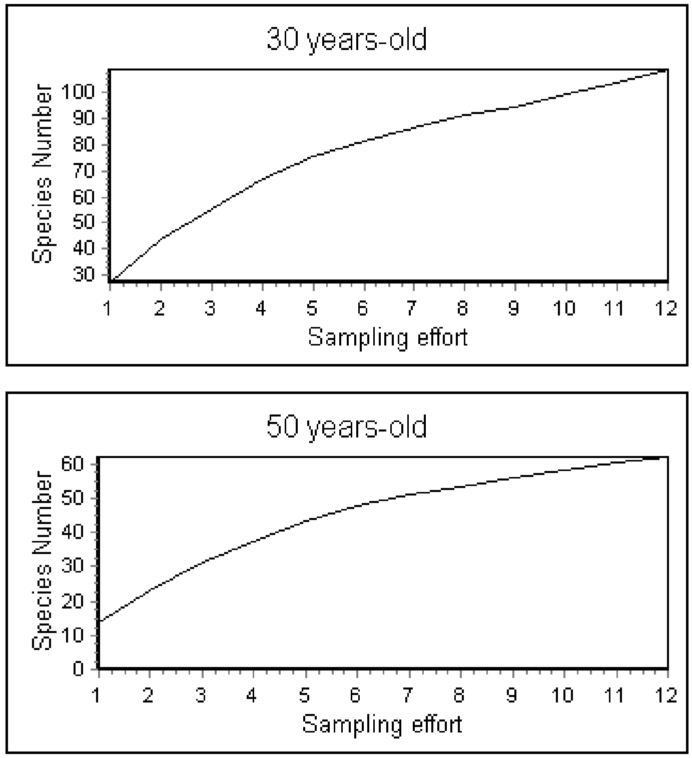


Figure 5.1-3: Species accumulation curve for bird's sampling in 30 and 50 years-old regenerated forests in Peninsular Malaysia.

Bird community inhibiting 30 and 50 years-old regenerated forests was not distributed normally (number of individual caught per species). Both study sites showed a lower p value than required by the normal distribution ($p>0.05$). In addition the values of skewness and kurtosis for both study sites was not approaching zero value and this was further indicated that the species caught in both study areas was not normally distributed (Table 5.1-6)

Table 5.1-6: A normal distribution test indicated species community caught during the sampling in the 30 and 50 years-old regenerated forests was not normally distributed.

Test	30 years-old	50 years-old
Kolmogorov-Smirnoff	0.36	0.32
p > 0.05	0.00*	0.00*
Skewness (± SE)	6.38 ± 0.23	33.79 ± 0.3
Kurtosis (± SE)	52.42 ± 0.46	33.79 ± 0.6

* = Non-significant.

Majority of the species captured in both forests were caught in abundance of one to five individuals. Sixteen species in the 30 years-old forest and 12 species in 50 years-old regenerated forest have abundance of six to 10 individuals (Figure 5.1-4). Only single species was caught with an abundance of 180 individuals in the 30 years-old forest and 85 individuals in the 50 years-old forest (Figure 5.1-4).

No species were caught with an abundance ranging from 60 to 170 individuals in 30 years-old forest. While in 50 years-old forest no species were captured with an abundance ranging from 40 to 80 individuals (Figure 5.1-4).

Pycnonotidae (bulbuls) are the most frequently captured family in both study sites. Seventeen species (209 individuals) were caught in 30 years-old site and ten species were captured in 50 year-old site (68 individuals). Timalidae (babblers) are the second most abundant family captured in 30 years-old site. It was represented by 14 species (231 individuals) and the third most frequently caught species in the 50 years-old site with seven species representatives (49 individuals). Muscicapidae (flycatchers) are the second most abundant family caught in 50 years-old site (4 species and 20 individuals) and third most abundant species in 30 years-old site (8 species and 30 individuals) (Table 5.1-1).

Little Spiderhunter were the most abundant species recorded in 30 years-old forest (15.0 ± 14.9) followed by Black headed Bulbul (4.33 ± 7.5) and Short tailed Babbler (3.58 ± 4.7) (Table 5.1-7). The most abundant species in 50 years-old site demonstrated by Orange-bellied Flowerpecker (7.08 ± 12.16) followed by Little Spiderhunter (2.67 ± 3.89) and Striped tit Babbler (1.75 ± 3.55) (Table 5.1-8).

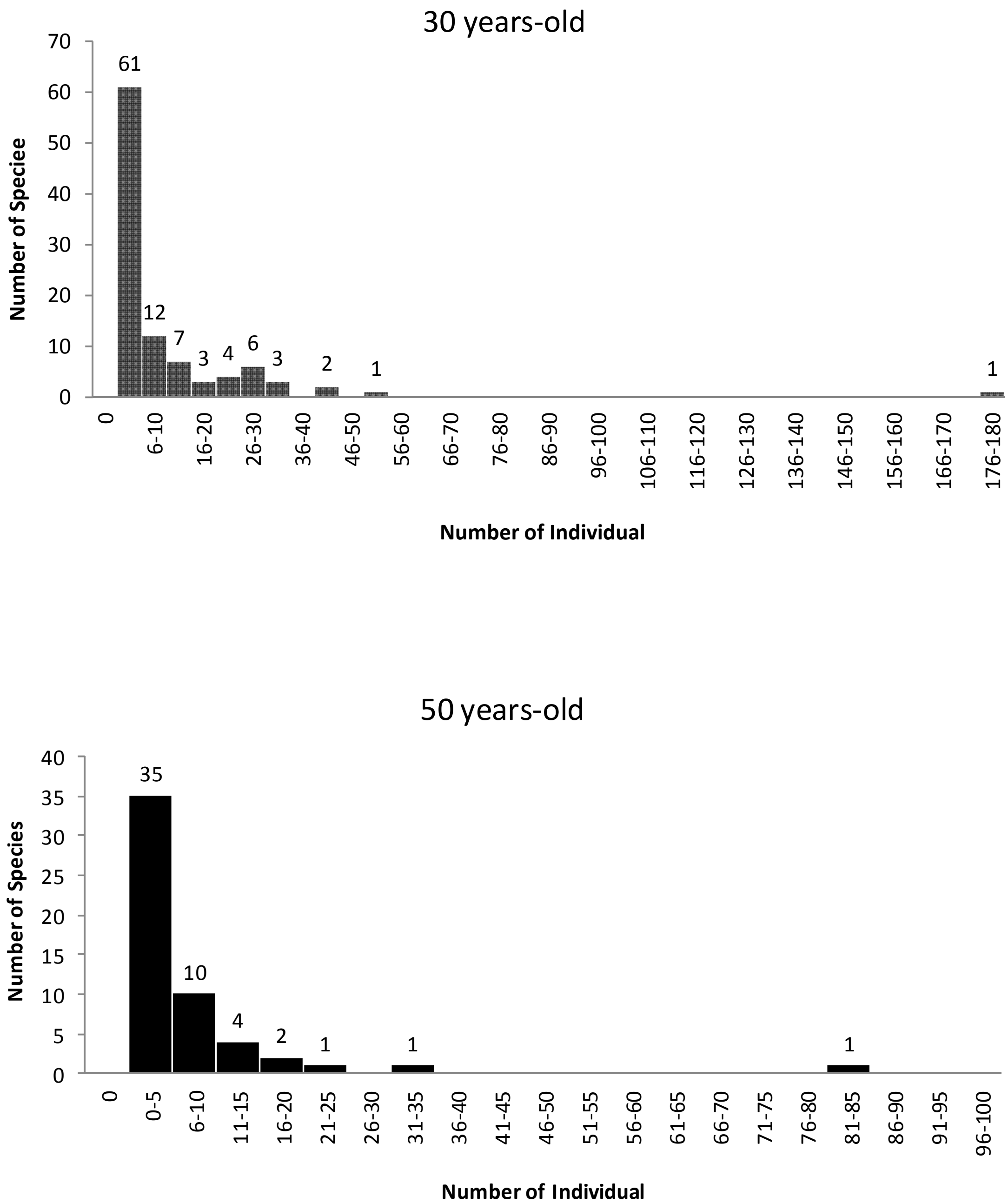


Figure 5.1-4. Frequency of birds species caught during the sampling in the 30 and 50 years-old regenerated forests, in Peninsular Malaysia.

Table 5.1-7: The most abundant bird species caught in 30 years-old regenerated forest (minimum number listed is 12 individuals). Number of individuals is followed by percentage of individuals in parentheses.

No.	Species	Total
1	Little Spiderhunter	180 (16.7)
2	Black headed Bulbul	52 (4.83)
3	Short tailed Babbler	43 (3.9)
4	Grey headed Babbler	41 (3.8)
5	Grey cheeked Bulbul	34 (3.2)
6	Yellow breasted Flowerpecker	34 (3.2)
7	Grey throated Babbler	34 (3.2)
8	Black capped Babbler	29 (2.7)
9	Purple naped Sunbird	29 (2.7)
10	Striped tit Babbler	29 (2.7)
11	Hairy backed Bulbul	28 (2.6)
12	Oriental dwarf Kingfisher	28 (2.6)
13	Yellow bellied Bulbul	26 (2.4)
14	White rumped Shama	25 (2.3)
15	Rufous winged Monarch	21 (1.9)
16	Grey breasted Spiderhunter	21 (1.9)
17	Crimson breasted Flowerpecker	21 (1.9)
18	Chestnut winged Babbler	20 (1.8)
19	Rufous tailed Tailorbird	20 (1.8)
20	Chestnut naped Forktail	18 (1.6)
21	Yellow bellied Warbler	15 (1.4)
22	Emerald Dove	12 (1.1)
23	Rufous Piculet	12 (1.1)
24	Spectacled Bulbul	12 (1.1)

Table 5.1-8: Most abundant bird species caught in 50 years-old regenerated forest (minimum number listed is 12 individuals). Number of individuals is followed by percentage of individuals in parentheses.

No	Species	Total
1	Orange bellied Flowerpecker	85 (20.9)
2	Little Spiderhunter	32 (7.9)
3	Striped tit Babbler	21 (5.2)
4	Red eyed Bulbul	20 (4.9)
5	Grey breasted Spiderhunter	16 (3.9)
6	Black headed Bulbul	15 (3.7)
7	Grey throated Babbler	14 (3.5)
8	Purple naped Sunbird	12 (2.9)
9	White rumped Shama	12 (2.9)

5.1.3. Diversity Analysis

Species diversity is greater in the 30 years-old forest (R_1 =15.47) than the 50 years-old forest (R_1 =10.16). The species evenness and between the two study sites was quite similar statistically, the distribution of individuals among species was more uneven in the 30 years-old forest (E = 0.21) than the 50 years-old forest (E = 0.25). While Shannon-Weiner index indicated that the species composition was higher in 30 years-old forest (H = 3.82) compared to 50 years-old forest (H = 3.38) though both values was quite similar statistically. The similar pattern was shown by Simpson (D) index which indicated that species abundant was higher in 30 years-old forest (D = 22.61) than 50 years-old forest (D = 15.45) (Table 5.1-9).

The variation of species diversity in the 30 years-old forest showed significant differences. The highest species richness was in sampling station 5 (H = 3.58) while the lowest was in sampling station 8 (H = 0.64) (Table 5.1-10).

This index indicated that the estimated probability of the diversity in the 30 years-old forest indicated that the species composition in site 2 is more diverse than site 1 (difference between indices = 0.86; estimated probability that diversities are equal, E = 0.04, $p<0.05$). Species composition in sampling station 2 is same with station 3 but these samples are more diverse than station 4 and station 5 (Table 5.1-9 and Table 5.1-10).

Table 5.1-9: Diversity values of cumulative sampling in both study sites given by various diversity indices.

Diversity Indices	Study site			
	30 year-old		50 year-old	
	Index Value	S.E	Index Value	S.E
Species richness				
No.	100		54	
R_1	15.47	0.93	10.16	0.74
Species diversity				
H	3.82	0.058	3.38	0.17
D	22.61	3.58	15.42	5.99
BPD	0.17	0.023	0.21	0.05
Species evenness				
E	0.21	0.04	0.25	0.1

(No = Total number of species; R_1= Margalef index; H = Shannon index; D = Simpson index; BPD = Berger Parker Dominance; E = Evenness index).

Table 5.1-10: Species diversity in each of 12 sampling station in the 30 year-old and the 50 year-old regenerated forest in Peninsular Malaysia. Values highlighted in bold indicated the highest index among the 12 sampling stations.

Sampling Station	Diversity Indices							
	30 year-old				**50 year-old**			
	H'	D	BPD	E	H'	D	BPD	E
S1	1.76	7.00	0.43	0.10	1.27	5.25	0.36	0.31
S2	2.62	20.30	0.17	0.27	2.25	33.00	0.14	0.33
S3	3.38	**32.04**	0.19	0.84	2.65	16.53	0.08	**0.92**
S4	3.09	17.66	0.22	0.54	**2.73**	10.88	0.17	0.36
S5	**3.58**	24.88	0.33	0.47	2.52	7.28	0.13	0.29
S6	3.17	12.88	0.35	0.29	2.48	2.00	0.24	0.36
S7	3.37	24.93	0.14	0.58	2.54	23.10	0.12	0.16
S8	3.07	16.92	**0.67**	0.55	0.63	3.00	0.17	0.15
S9	2.78	18.72	0.11	**0.94**	2.72	**27.00**	0.17	0.15
S10	2.32	10.71	0.14	0.82	2.53	23.33	0.28	0.17
S11	2.18	6.37	0.23	0.46	2.05	13.00	**0.38**	0.14
S12	2.19	11.33	0.50	0.13	0.69	2.00	0.29	0.10

(H' = Shannon-Weiner index; D = Simpson index; BPD = Berger-Parker Dominance index; E = Evenness index)

5.1.4. Comparisons Between Diversity Indices

The variation in bird species diversity within 12 sampling stations did occur in the 30 and 50 years-old regenerated forests. Simpson diversity index indicated that the high species diversity in 30 years-old forest was recorded in station 3 while less species diversity were recorded in sampling station 1 and sampling station 11. Similar pattern of bird captured showed by the sample-based rarefaction curve (Figure 5.1-7).

However in 50 years-old site, high species diversity was recorded in sampling station 2 while the lowest diversity were recorded in sampling station 3 and station 11 (Table 5.1-10 and Figure 5.1-5).

Reversed trend shown by Berger-Parker alpha diversity index (the population approach in determining community evenness). The 50 years-old forest (BPD = 0.209, Jackknife SE = 0.054) recorded high community evenness than the 30 years-old forest (BPD = 0.167, Jackknife SE = 0.024) (Table 5.1-10 and Figure 5.1-5).

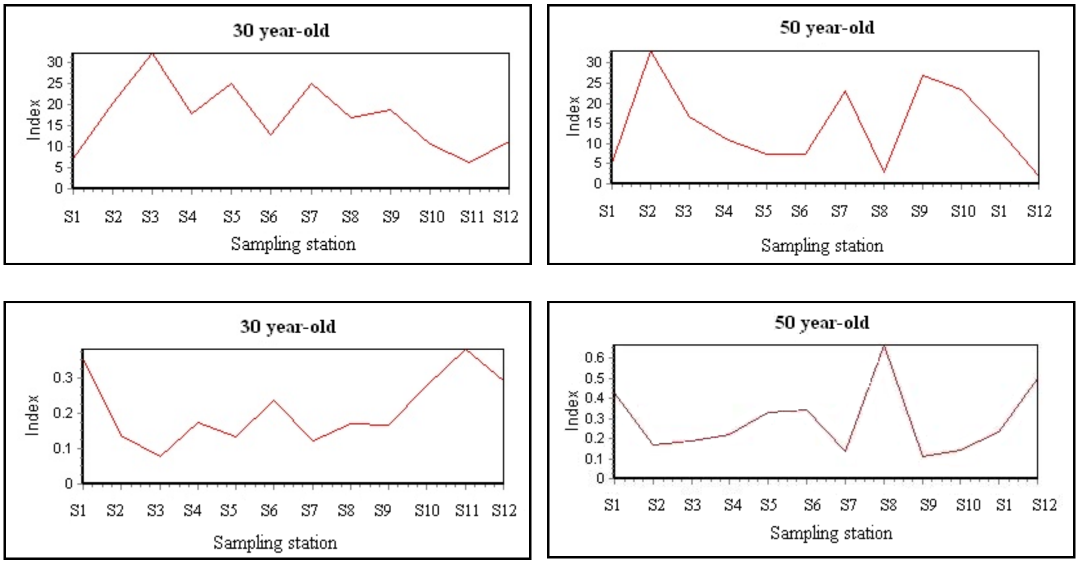


Figure 5.1-5: Comparison between indices of species richness and abundance in 50 year-old forest and 30 year-old forest. Top: Simpson D, Below; Berger-Parker Dominance.

In contrary to Shannon-Weiner, the values of Simpson D and Berger Parker Dominance (BPD) have strong relation in describing species richness and abundance in similar situation (both indices emphasis more on evenness) (Figure 5.1-5 and Table 5.1-10). The species richness was higher in 30 year-old forest and slightly lower in 50 years-old forest (for Simpson D). The result from Simpson D in 30 years-old forest indicated that the community becomes constantly less diverse as sampling move towards to the end (until sampling station 12). However in 50 years-old forest bird's community does not show a clear different between samplings and there is no clear pattern for the species richness and abundance. Bird's community showed high diversity in sampling station 2 until sampling station 7 and become less diverse in sampling station 8 (Figure 5.1-7).

The BPD which stresses more on the number of individuals within the species had showed similar trend with the Simpson D index. The trend shown by BPD in 30 years-old forest was the increasing pattern as sampling move towards the end. It also indicates that there is an increasing pattern of individual's abundance for a single species as sampling effort increase. The increasing pattern also emphasis that the community in a sample area is more diverse. Similarly the number of individual for a single species is higher in sampling station 8 and there were no clear pattern for other samples in 50 years-old forest.

The index also indicates increasing pattern of individual's abundance for a single species as sampling effort increase. The increasing pattern shows that the bird community in a study area has less species but many individuals representative for each species. This shown by BPD in 50 years-old forest as the number of individual for a single species is higher in sampling station 8 and no clear diversity pattern for other sampling stations. Bird diversity in sampling station 8 indicates that birds are more diverse than in September. This clearly agreed that BPD index is not sensitive to species abundance and richness.

In contrast to D index, evenness index clearly showed that species and individual are more evenly distributed in 50 year-old forest (0.2487 ± 0.102) than 30 years-old forest (0.2074 ± 0.044) (sample index ± Jack SE) (Figure 5.1-6 and Table 5.1-10).

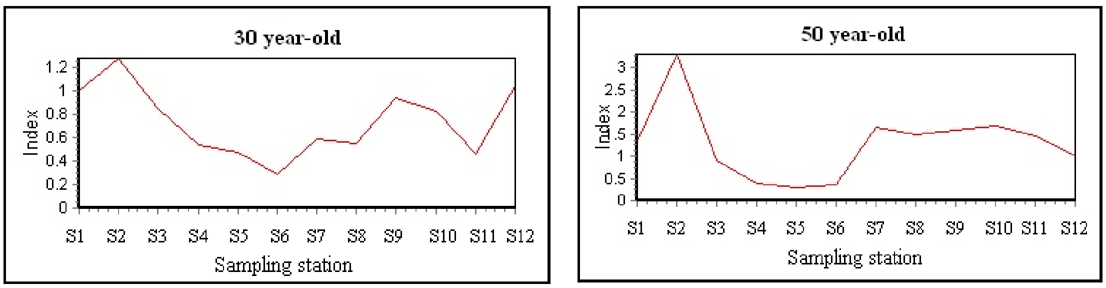
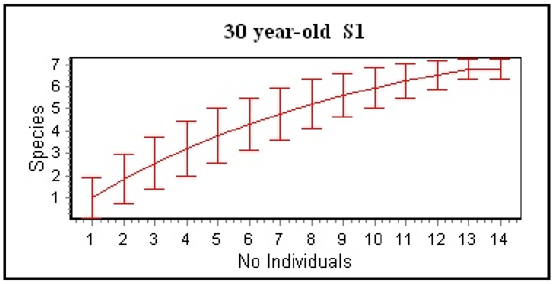
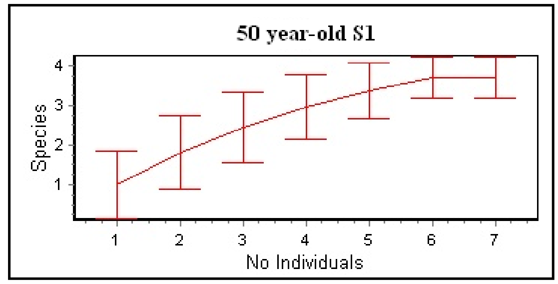
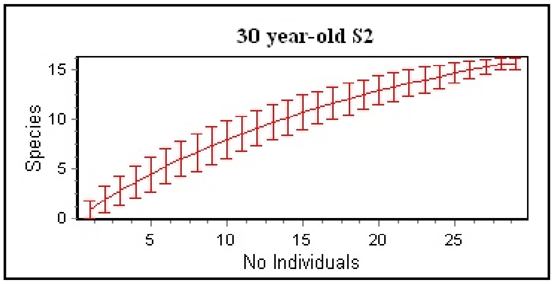
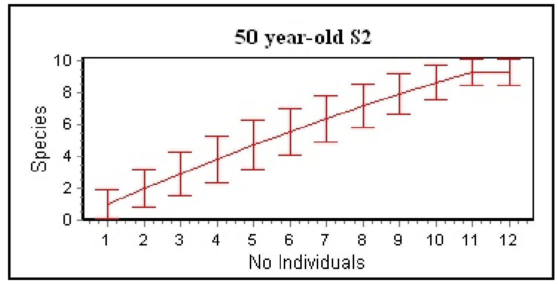


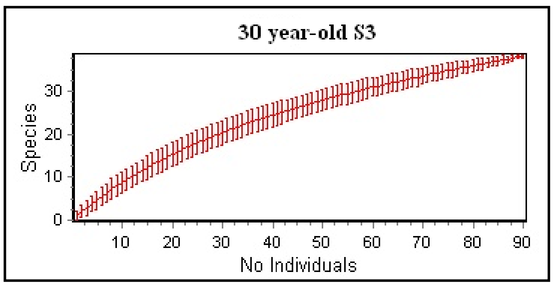
Figure 5.1-6: Plot for Simpson E (Evenness) for both study sites.

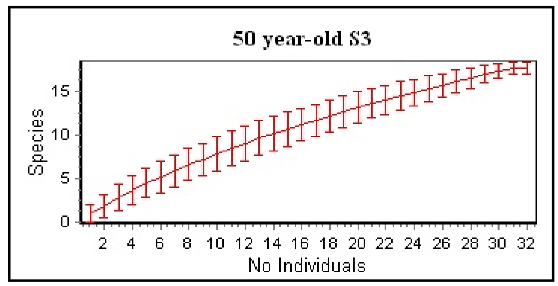

30 year-old S1
Species
No Individuals

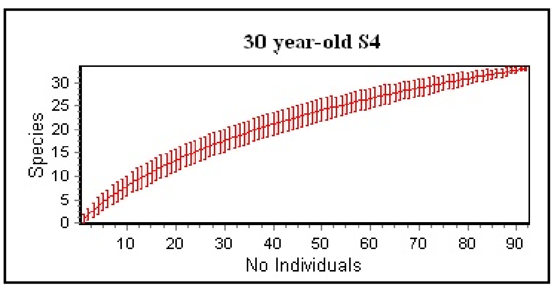

50 year-old S1
Species
No Individuals

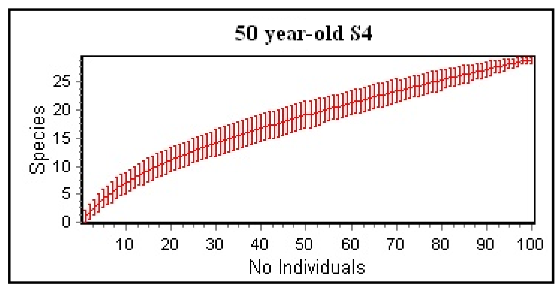

30 year-old S2
Species
No Individuals

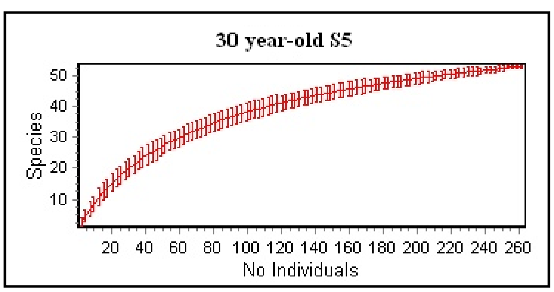

50 year-old S2
Species
No Individuals

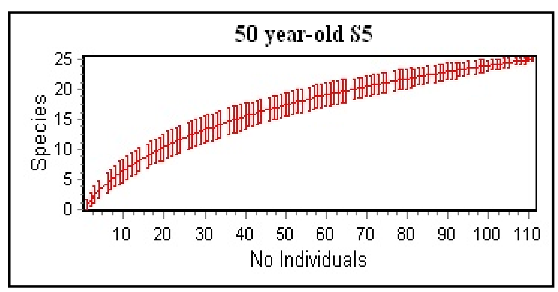

30 year-old S3
Species
No Individuals

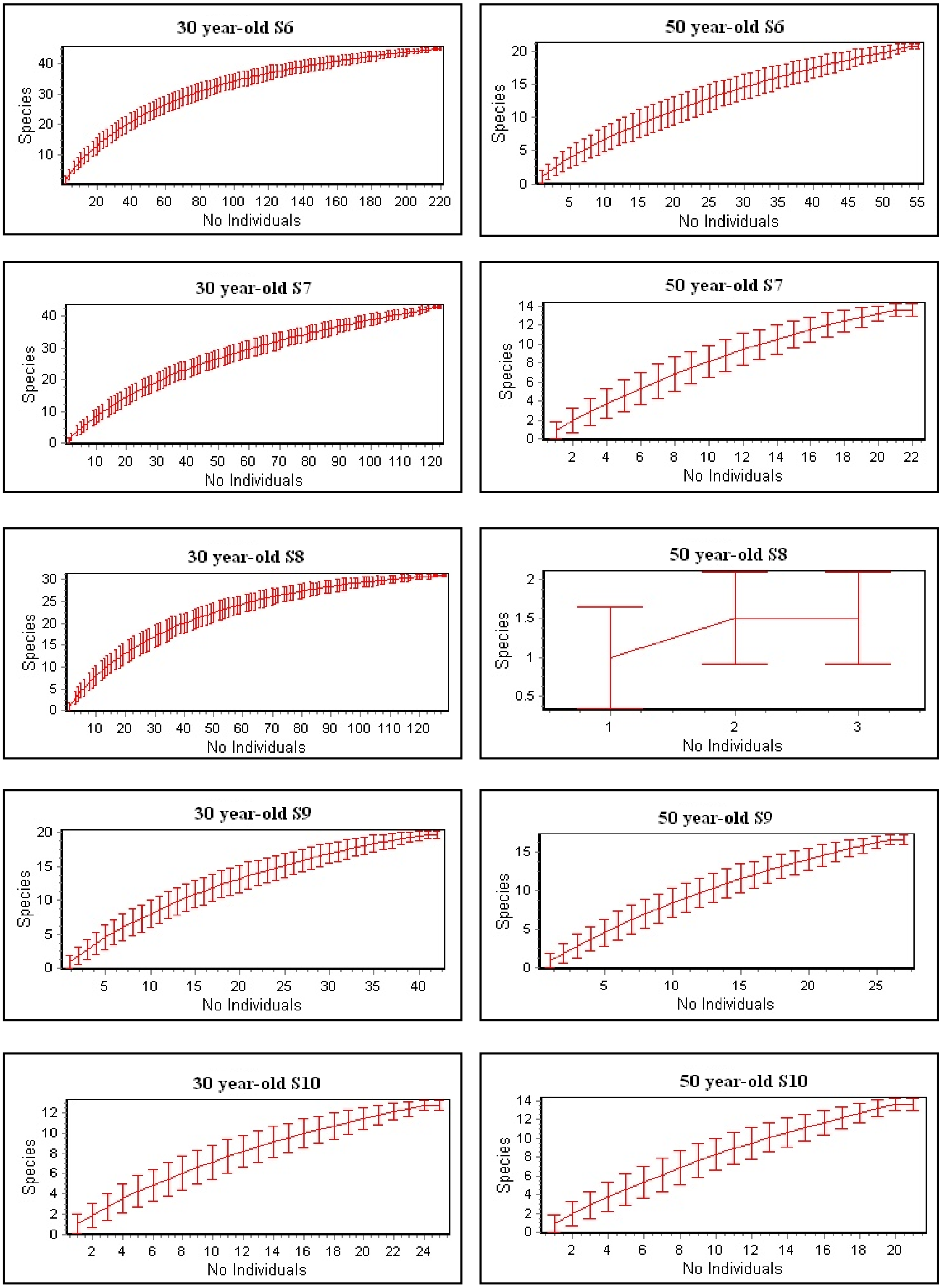

50 year-old S3
Species
No Individuals


30 year-old S4
Species
No Individuals


50 year-old S4
Species
No Individuals


30 year-old S5
Species
No Individuals


50 year-old S5
Species
No Individuals


30 year-old S6
Species
No Individuals
50 year-old S6
Species
No Individuals
30 year-old S7
Species
No Individuals
50 year-old S7
Species
No Individuals
30 year-old S8
Species
No Individuals
50 year-old S8
Species
No Individuals
30 year-old S9
Species
No Individuals
50 year-old S9
Species
No Individuals
30 year-old S10
Species
No Individuals
50 year-old S10
Species
No Individuals

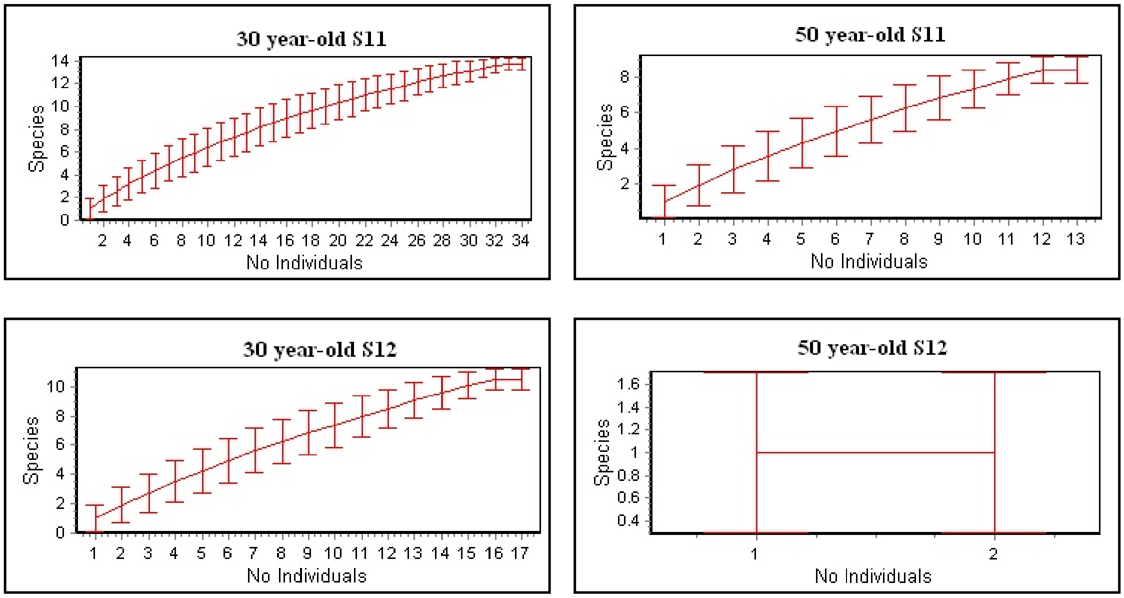


Figure 5.1-7: Sample-based rarefaction curve displaying bird species richness in each 12 sampling stations within 30 year-old regenerated forest and 50 year-old regenerated forest, in Peninsular Malaysia. (S1 to S12 representing the sampling station).

5.1.5. Species Composition and Similarity between and within sites

The 30 and the 50 years-old regenerated forests was not differed significantly in term of mean community abundance (number of individual per species) (Mann-Whitney U test; p = 0.14) (Figure 5.1-8).

The number of bird species per sampling varies from 7 to 53 (27.0 ± 15.4) in 30 years-old regenerated forest and from 2 to 29 (13.7 ± 8.7) in the 50 years-old regenerated forest. The number of individual per species varies from 1 to 180 in the 30 years-old regenerated forest (9.88 ± 1.88) and from 1 to 85 in the 50 years-old regenerated forest (6.53 ± 1.48).

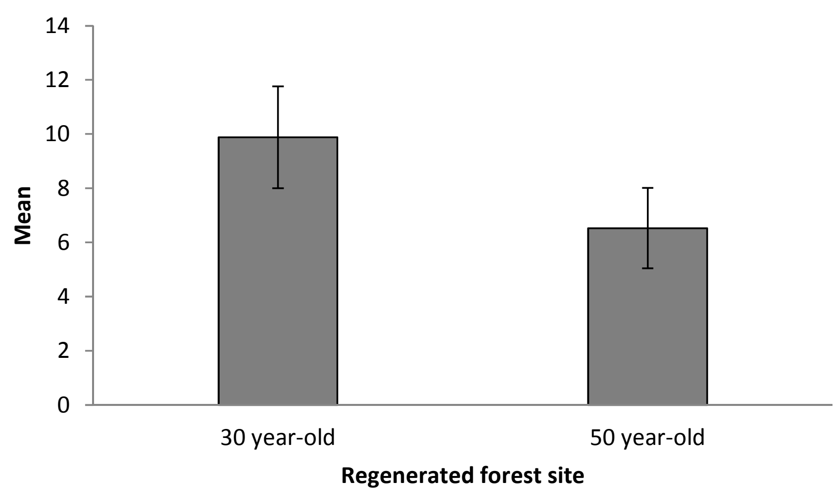


Figure 5.1-8: Mean community abundance (number of individual per species) of bird present in the 30 and 50 years-old regenerated forests.

There was a significant different of species composition (with respect of species relative abundance) between 30 and the 50 years-old regenerated forests ($\chi^2 = 152.4$, df = 1, $p < 0.05$).

Of total number of species captured, 15 species differed significantly between study sites. The population of Little Spiderhunter ($\chi^2 = 4.37$, p = 0.000), Short-tailed Babbler, Stripe tit Babbler ($\chi^2 = 1.48$, p = 0.020) and Black capped Babbler ($\chi^2 = 2.38$, p = 0.030) was significantly more numerous in the 30 years-old than the 50 year-old regenerated forest (Table 5.1-11).

The proportion of Orange bellied Flowerpecker ($\chi^2 = 131.63$, p = 0.00), Plain Sunbird ($\chi^2 = 2.98$, p = 0.043) and Red-eyed Bulbul ($\chi^2 = 11.38$, p = 0.000) was significantly higher in 50 years-old regenerated forest than in 30 years-old regenerated forest (Table 5.1-11).

A total of 9 singleton species were caught in 30 years-old regenerated forest but was not detected in 50 years-old regenerated forest. These are Red throated Barbet (*Megalaima mystacophanos*), Dark throated Oriole (*Oriolus xanthonotus*), Crested Jay (*Platylophus galericulatus*) Blue winged Leafbird (*Chloropsis cochinchinensis*), Spotted Fantail (*Rhipidura perlata*), Asian fairy Bluebird (*Irena puella*), Oriental White-eye (*Zosterops palpebrosus*) and Everette's White-eye (*Zosterops everetti*).

Table 5.1-11: Species differ significantly in relative abundance between the 30 and 50 years-old regenerated forests. O = observed abundance (total bird captured), E = expected abundance and χ^2 = Chi-square at p<0.05.

Species	30 year-old			50 year-old			p
	O	E	χ^2	O	E	χ^2	
Black capped Babbler	29	21.80	2.38	1	8.20	6.32	0.03
Black naped Monarch	11	7.99	1.13	0	3.01	3.01	0.04
Chestnut winged Babbler	20	14.53	2.06	0	5.47	5.47	0.01
Grey breasted Spiderhunter	21	26.89	1.29	16	10.11	3.43	0.00
Grey headed Flycatcher	0	5.81	5.81	8	2.19	15.46	0.00
Little Spiderhunter	180	154.07	4.37	32	57.94	11.61	0.00
Orange bellied Flowerpecker	11	69.77	49.5	85	26.24	131.63	0.00
Plain Sunbird	5	7.99	1.12	6	3.01	2.98	0.04
Red-eyed Bulbul	15	25.44	4.28	20	9.57	11.38	0.00
Rufous chested Flycatcher	1	4.36	2.59	5	1.64	6.89	0.00
Scarlet backed Flowerpecker	0	4.36	4.36	6	1.64	11.60	0.00
Short tailed Babbler	43	33.43	2.74	3	12.57	7.29	0.00
Streak eared Bulbul	0	1.45	1.45	2	0.55	3.87	0.02
Striped tit Babbler	29	36.34	1.48	21	13.66	3.94	0.02
Yellow bellied Bulbul	26	19.62	2.07	1	7.38	5.51	0.01

The percentage of the community similarity indicated by Jaccard's Coefficients between the 30 years-old regenerated forest and the 50 years-old regenerated forest was 42.5% (Figure 5.1-9). The species that only present/caught in 30 years-old regenerated forest (54 species or 50%) was higher than the species that only occur in the 50 years-old regenerated forest (8 species or 7.4%) (Appendix 1).

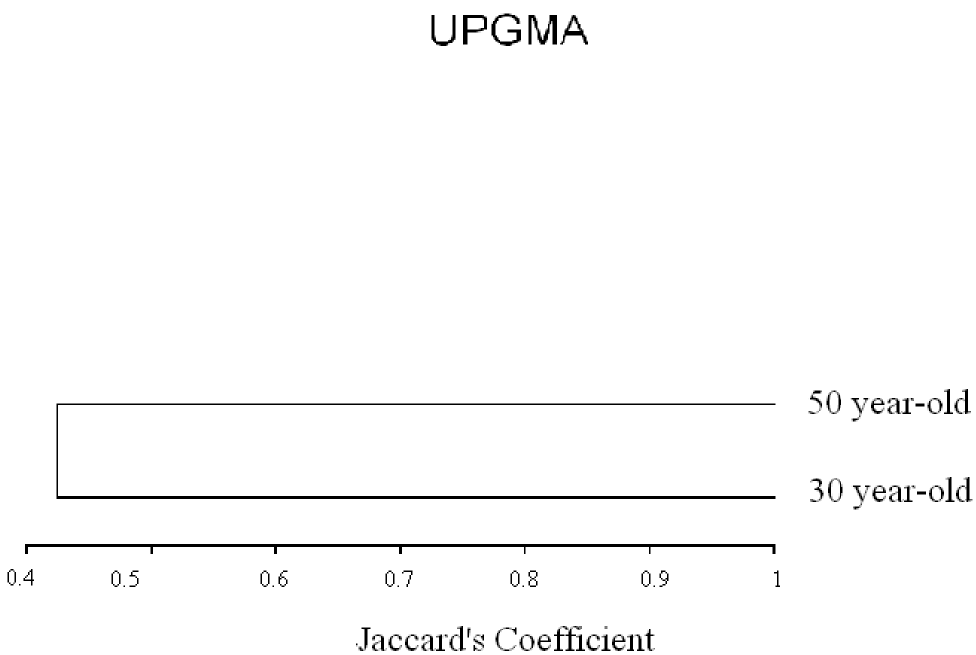


Figure 5.1-9: Dendogram of percentage of bird community similarity inhabiting 30 and 50 years-old regenerated forests, in Peninsular Malaysia.

Based on the record of species presence and absence within the 30 years-old regenerated forest, the percentage of species similarity occur between sampling station 5 and sampling station 7 is at 43% (Figure 5.1-10). A total of 28 species present at both sampling station. Of total species present, three species only occurred at these sites at 100% similarity and these were Verditer Flycatcher, and Dark necked Tailorbird. Others species that utilized both sites were Ruby cheeked Sunbird, Orange bellied Flowerpecker and Abbots Babbler.

The percentage of species similarity between sampling station 3 and sampling station 4 was at 41.2% (Figure 5.1-10). A total of 20 similar species utilized both stations and several most abundant was Grey cheeked Bulbul, Hairy backed Bulbul, Oriental dwarf Kingfisher and Hill blue Flycatcher.

Another closely similar species composition per sampling station in 30 years-old regenerated forest was sampling station 2 and 12, and sampling station 1 and 11 with species similarity percentage at 23 % and 22% respectively (Figure 5.1-10). The common species present at sampling station 2 and 12 were Yellow bellied Bulbul and Oriental dwarf Kingfisher. While Red eyed Bulbul were frequently occurred in sampling station 1 and 11.

Species composition in sampling station 9 was closely related with the several sites characterized by sampling station 3, 4, 5, 6, 7 and sampling station 8 with 24% of species similarity (Figure 5.1-10). Three similar species were occurred at all sites which include Short tailed Babbler, Grey throated Babbler and Purple naped sunbird.

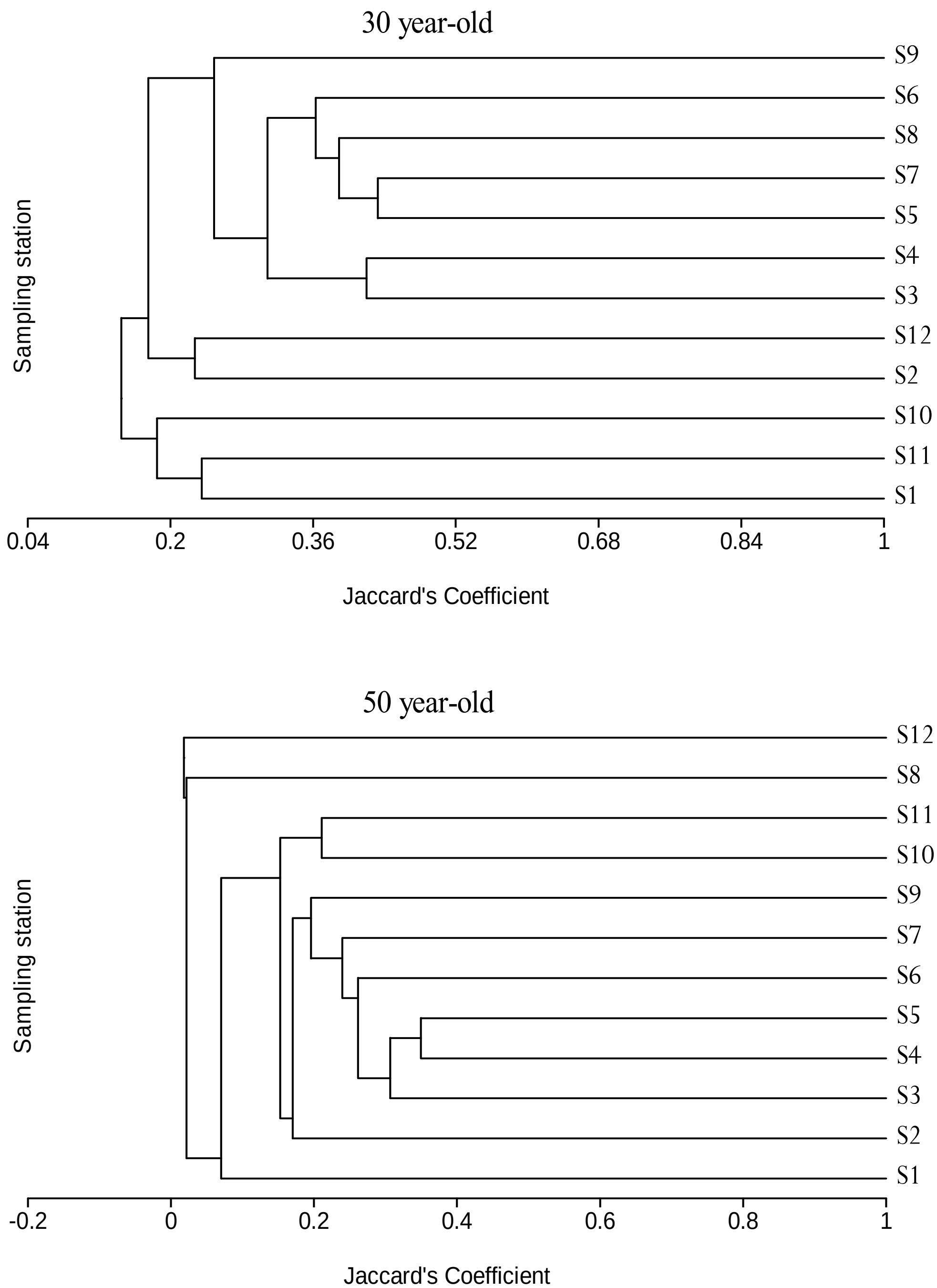


Figure 5.1-10: Dendogram percentage of habitat similarity based on the similarity of the species caught within the 30 years-old regenerated forest and the 50 years-old regenerated forest using UPGMA clustering method. Twelve established sampling stations (S1 to S12) representing various habitat types within both sites.

Overall percentage of species similarity within the 50 years-old regenerated forest sites was lower (similarity less than 40%) compared to similarity of species occurred within the 30 years-old regenerated forest (similarity more than 40%). Species composition was closely similar between the sampling station 4 and 5 and sampling station 10 and 11.

The highest percentage of similarity was detected in sampling station 4 and 5 (35%). A total of 14 species present in both sites. These include Striped tit Babbler, Striped-throated Babbler and Plain Sunbird. The percentage of similarity between sampling station 3 and node 1 (S4 and S5) was 31% with six similar species were present. Several species caught were Spectacled Bulbul, Striped throated Bulbul and White rumped Shama.

Most similar species composition displayed by the sampling station 10 and 11 with percentage of similarity was 21%. Three species was commonly utilized both sites and these were Siberian blue Robin, Purple naped Sunbird and Grey headed Babbler.

Species composition in sampling station 12 was highly dissimilar with other sampling stations within the 50 years-old regenerated forest. The percentage of similarity was only 18%. Only two species were caught and these were Brown chested Flycatcher and Mugimaki Flycatcher.

Generalist species (include more than one diets) including several migratory species tended to exploit/utilize similar sites within the established sampling stations in the 30 years-old and 50 years-old regenerated forest with the percentage of similarity more than 50%. (Figure 5.1-11 and Figure 5.1-12).

This was demonstrated by the species caught within the 30 years-old regenerated forest. The percentage of occurrence similarity between Yellow bellied Bulbul and Little Spiderhunter at 67%. While 57% of similarity displayed between Red eyed Bulbul and Grey breasted Spiderhunter.

Within the 50 years-old regenerated forest, the occurrence of Little Spiderhunter and Orange bellied Flowerpecker was detected similar at 68%. While 50% was detected between Scarlet backed Flowerpecker and Red eyed Bulbul.

Most of the terrestrial insectivores are characterized by Short tailed Babbler and White rumped Shama while foliage gleaning insectivores are characterized by Grey throated Babbler. These species were occurred in similar sites within the 30 years-old regenerated forest with the percentage of occurrence similarity more than 80%. Within same study sites, the percentage of occurrence similarity of sallying insectivores (Brown chested Flycatcher and Black naped Monarch) was 67%.

Bark gleaning insectivores were represented by Orange backed Woodpecker and Crimson winged Woodpecker. Both species were caught in same sampling sites within 30 years-old regenerated forest with percentage of occurrence similarity at 50%. Within same study areas, the occurrence similarity percentage between bark gleaning insectivores illustrated by Rufous Piculet and terrestrial insectivores by Black capped Babbler was 50%. In addition, both of these species was caught within the same sampling sites.

The presence of terrestrial insectivores were displayed by Streak eared Bulbul and Horsefield Babbler within the 50 years-old regenerated forest. These species occurred in similar sampling site with 100% occurrence similarity. Within same study sites, the presence of the sallying insectivores (Rufous chested Flycatcher) and foliage gleaning insectivores (Grey throated Babbler) were detected with more than 80% occurrence similarity.

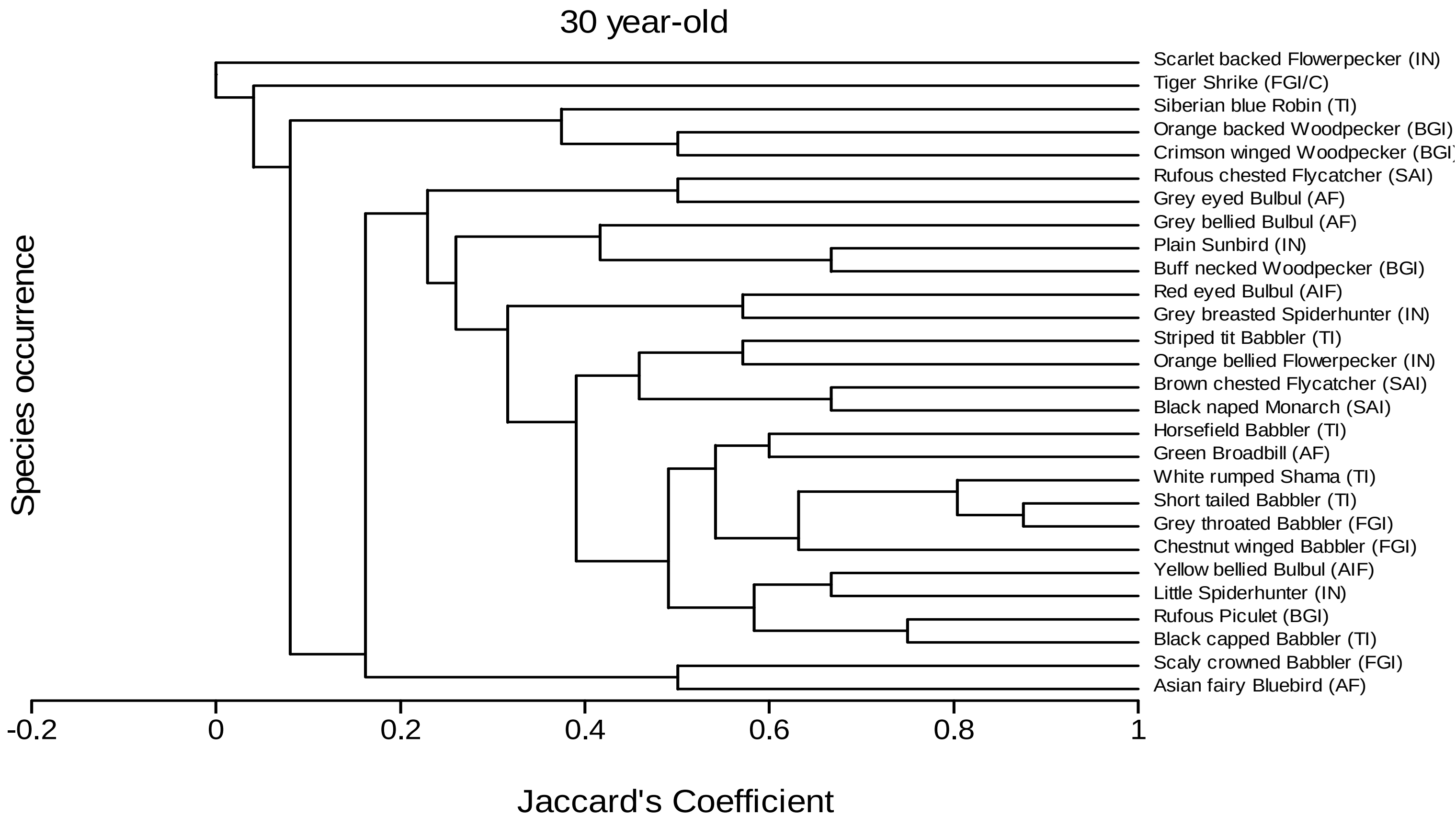


Figure 5.1-11: Dendogram percentage species that differ significantly in relative abundance between two regenerated forests (Table 5.1-11) and some selected species representing various feeding guild within 30 years-old regenerated forest. For feeding guild description refer to Table 5.1-13.

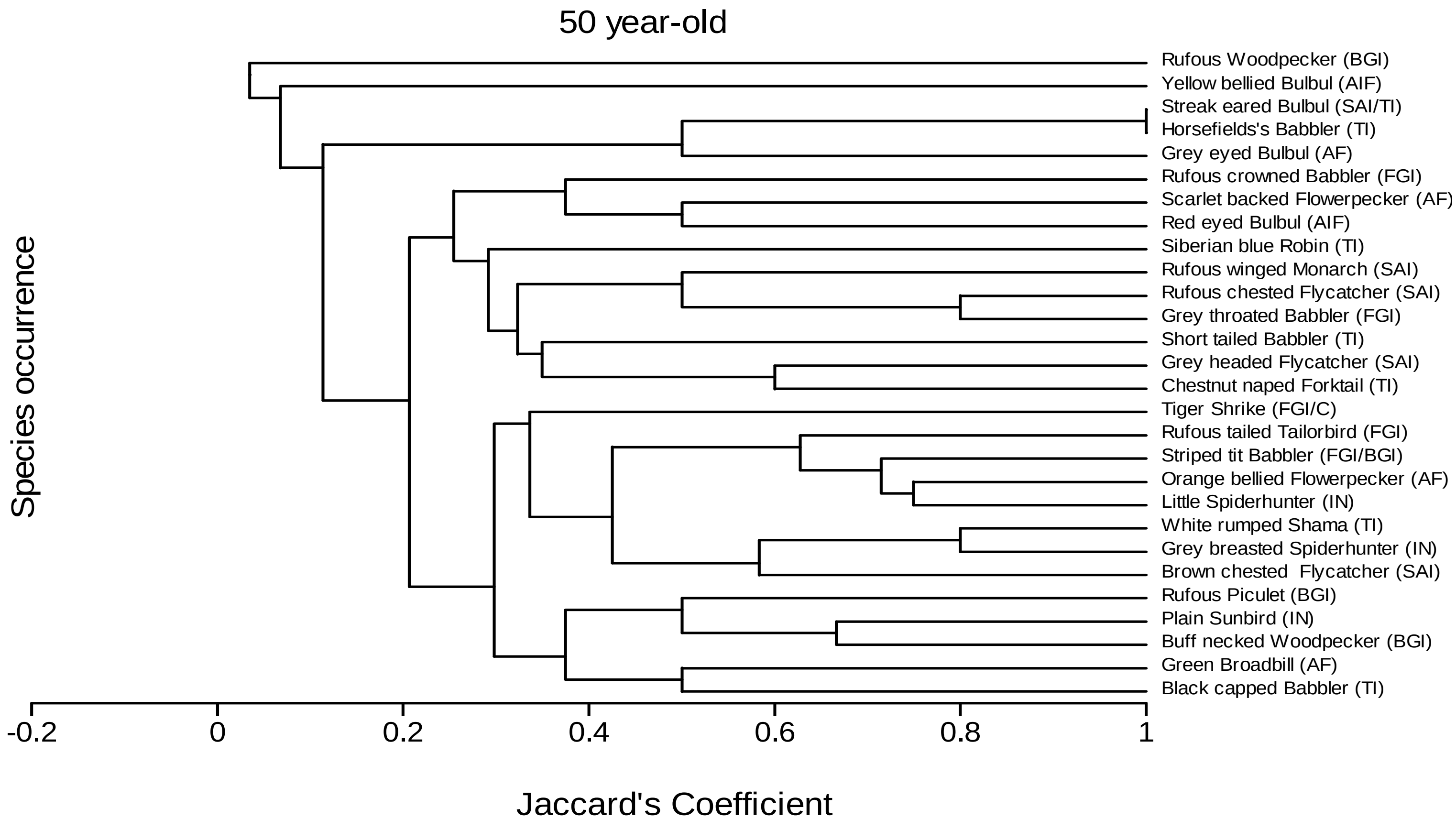


Figure 5.1-12: Dendogram percentage of species that differ significantly in relative abundance between two regenerated forests (Table 5.1-11) and some selected species representing various feeding guild within 50 years-old regenerated forest. For feeding guild description refer to Table 5.1-13.

5.2. Spaces Utilization by Understorey Bird

5.2.1. Overall

In this study, all captured individuals were considered utilized different strata of forest zones. The utilization of different forest strata are closely related to differences in feeding guilds.

5.2.2. Species Proportion Based on Space Utilization

Both study areas showed a similarity in species capture with majority of the species caught was active at both upper and middle storeys. Birds utilized different forest levels which basically related to their foraging technique and variation between species. According to Bransbury (1993), all birds' species should be divided into four groups, i.e. canopy, middle, lower and ground levels. However, the species that utilized canopy level was excluded in this study. This is because these species are not utilizing understorey zones and would not be sampled by mist-nets. An example of this species includes Glossy Swiftlet (*Collocalia esculenta*).

Majority of the species caught in the 30 years-old regenerated forest utilizing upper and middle levels (55%), followed by lower and ground levels (30.3%). There were 12 species (or 11%) that utilized middle, lower and ground levels as their foraging levels and three species that exploited resources at canopy, middle and lower levels, or at middle and lower levels (Figure 5.1-13; Appendix 4).

Of total species caught in 50 years-old regenerated forest, 46.3% utilized canopy and middle levels. These include several species of Bulbuls, Kingfishers, Babblers, Flycatchers, Sunbirds, Flowerpeckers, Woodpeckers and Spiderhunters (see Appendix 4).

There are 18 species (35.4%) that are utilizing lower and ground levels, followed by eight species (12.9%) that are active in the middle, lower and ground levels. Species utilized middle, lower and ground levels were Green-winged Pigeon (*Chalcophaps indica*), Grey-breasted Spiderhunter (*Arachnothera affinis*), Black-headed Bulbul (*Pycnonotus atriceps*), Grey-eyed Bulbul (*Iole propinqua*), Grey-headed Flycatcher *Culicicapa ceylonensis*, Rufous-collared Kingfisher (*Actenoides concretus*) and Tickle-blue Flycatcher (*Cyornis tickelliae*).

Another three species (4.8%) that utilized upper, middle and lower storeys were Green Broadbill (*Calyptomena viridis*), Rufous Piculet (*Sasia abnormis*) and Spectacled Bulbul (*Pycnonotus erythropthalmos*).

The 50 years-old regenerated forest do not harbour any species that utilized both middle and lower levels.

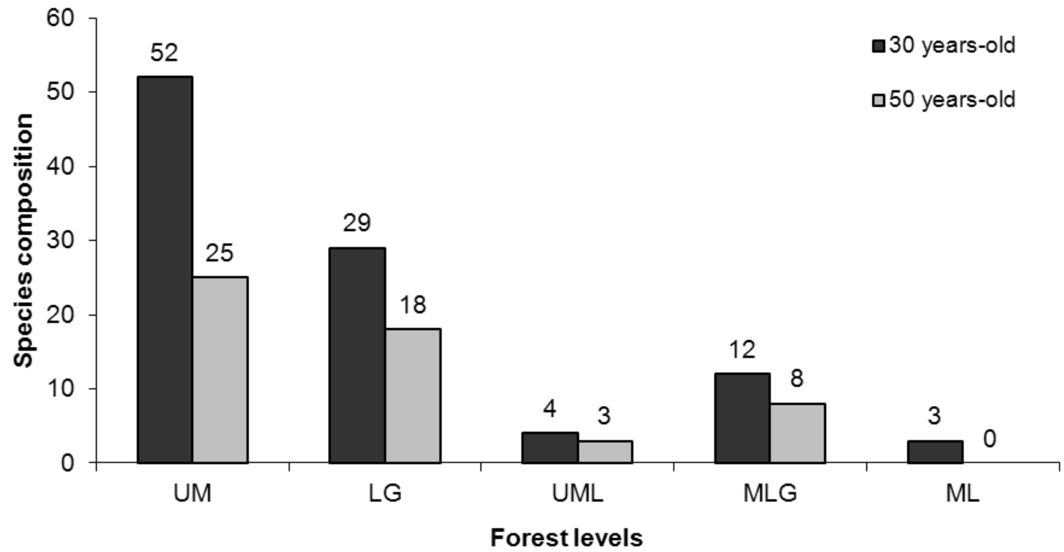


Figure 5.1-13: Species composition according to space utilization of forest understorey in both areas (UM = Upper and Middle levels, LG = Lower and Ground levels, UML = Upper, Middle and Lower levels, MLG = Middle, Lower and Ground levels, ML = Middle and Lower levels).

5.3. Trophic Guild Structure

5.3.1. Feeding guild

Of the four dietary feeding guild, frugivores and insectivores were differed significantly in relative abundance between both study sites. Frugivores comprised of higher proportion of birds sampled in the 50 than in 30 years-old regenerated forests ($\chi^2 = 53.93$, $p = 0.00$). While the proportion of insectivores was significantly higher in 30 than in 50 years-old regenerated forests ($\chi^2 = 1.29$, $p = 0.01$) (Table 5.1-12).

Generalist was the majority bird sampled in the 30 and the 50 years-old regenerated forests (Figure 5.1-15 and Table 5.1-12). However it was not significantly different between sites ($p = 0.35$). More generalist species was recorded in the 30 years-old regenerated forest (27 species 471 individuals) than in the 50 years-old regenerated forest (21 species 150 individuals).

The numbers of seed eaters or granivores between both study areas was significantly different ($p = 0.00$) (Table 5.1-12). This comprised of relatively smaller proportion of bird sampled in 30 years-old regenerated forest (three species and seven individuals) as well as in 50 years-old regenerated forest (1 species and 1 individual).

In term of number of individuals per species (mean proportion), frugivores in 50 years-old regenerated forest comprising highest individuals per species while the generalist species had a higher individuals per species in 30 years-old regenerated forest. Seed eaters consistently had lower individuals per species in both study sites (Table 5.1-12 and Figure 5.1-14)

Table 5.1-12: Total number of species and individual and number of individuals per species belonging to each feeding guild present in 30 years-old regenerated forest and 50 years-old regenerated forest in Peninsular Malaysia.

Feeding guild	**30 years-old**			**50 years-old**			*P<.05*
	No. of species	No. of individuals	Mean (SE)	No. of species	No. of individuals	Mean (SE)	
Insectivores	56	441	7.9 (1.4)	27	125	4.6 (0.9)	0.00*
Frugivores	10	87	8.7 (3.4)	6	108	18.0 (13.4)	0.00*
Generalist	27	471	17.4 (6.7)	21	150	6.3 (2.1)	0.35
Carnivores	4	37	9.3 (6.4)	3	8	2.7 (1.7)	0.15
Seed	3	7	2.3 (1.3)	1	1	1.0 (0.0)	0.00*

* = significant different between both study sites. Calculated with chi-square test.
Insectivores = arboreal, terrestrial, foliage gelaning, bark-gleaning and sallying. **Generalist** = arboreal insectivores/frugivores, terrestrial insectivores/frugivores, insectivores/nectarivores, foliage-gleaning insectivores/carnivores, sallying insectivores/arboreal frugivores and insectivores/nectarivores/arboreal frugivores.

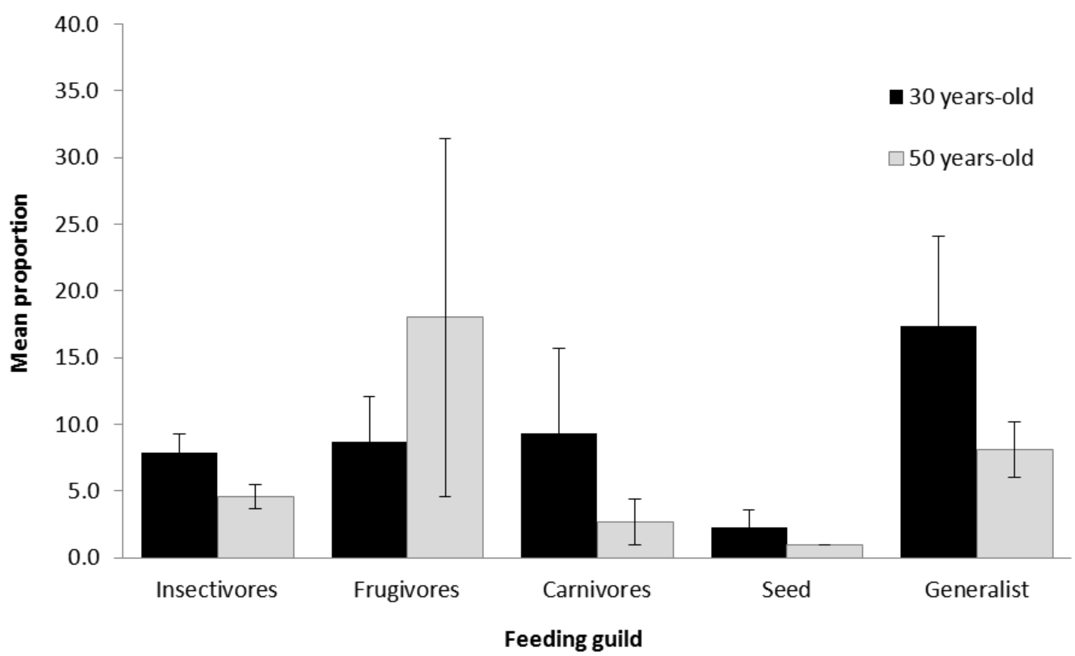


Figure 5.1-14: Number of individual per species (mean proportion) for feeding guilds present in the 30 and 50 years-old regenerated forests, in Peninsular Malaysia.

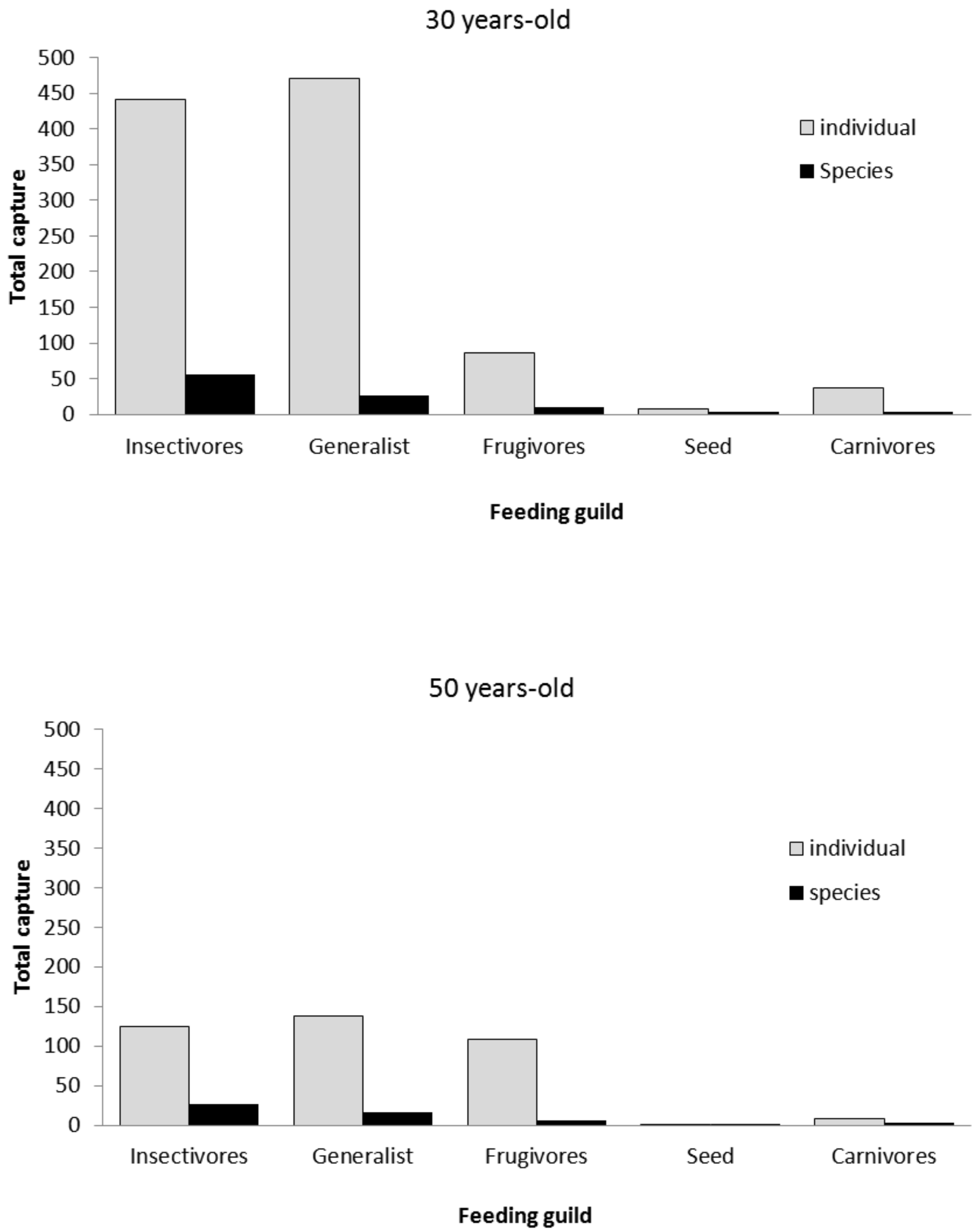


Figure 5.1-15: Feeding guild (based on total capture) of the understorey bird community in the 30 and 50 years-old regenerated forests. Generalist group was contributed by species with diets consists of two or more food sources (Edwards et al. 2009).

5.3.2. Foraging-feeding guild

Fourteen (14) foraging-feeding guilds were present in 30 years-old regenerated forest. Of these only 11 foraging-feeding guilds were observed in 50 years-old regenerated forest. Five foraging-feeding guilds differed significantly between both sites (Table 5.1-13).

Members of arboreal frugivores (AF) and foliage-gleaning insectivores/carnivores (FGI/C) differed significantly in relative abundance between both sites. Both of these foraging-feeding guilds were significantly numerous in the 50 years-old regenerated forest (AF, $\chi^2 = 59.86$, $p = 0.00$; FGI/C, $\chi^2 = 9.05$, $p = 0.01$) than in the 30 years-old regenerated forest (Table 5.1-13).

The insectivores/nectarivores ($\chi^2 = 1.60$, $p = 0.02$) and terrestrial insectivores ($\chi^2 = 2.29$, $p = 0.00$) was significantly more abundant in 30 years-old regenerated forest than the 50 years-old regenerated forest (Table 5.1-13 and Figure 5.1-16).

More members of foliage-gleaning insectivores detected in the 30 years-old regenerated forest ($\chi^2 = 1.07$, $p = 0.08$) than in the 50 years-old regenerated forest. However it was not significantly different between both sites (20.9% in 30 years-old and 16.3% in 50 years-old forests)

Three foraging-feeding guilds were not detected in 50 years-old regenerated forest. This were arboreal insectivores (AI) and group which includes more than one foraging-feeding guild techniques; insectivores and nectarivores/arboreal frugivores (IN/AF) and Sallying insectivores/arboreal frugivores (SAI/AF). However, these groups comprise a smaller portion of bird sampled in 30 years-old regenerated forest (Table 5.1-13).

In term of number of individual per species (mean proportion), insectivores/nectarivores (IN) consist a higher proportion of individuals per species in the 30 years-old regenerated forest while arboreal frugivores (AF) consistently comprise of a higher number of individual per species in the 50 years-old regenerated forest (Figure 5.1-12) (Figure 5.1-17).

More individual per species of terrestrial insectivores (TI) detected in the 30 years-old regenerated forest than the 50 years-old regenerated forest. Current study was able to record only one species from member of terrestrial frugivores (TF) in both study areas (12 and five individual was caught in the 30 years-old and 50 years-old regenerated forests respectively) (Table5.1-13).

Both study areas recorded followed by arboreal insectivores/frugivores (AIF) (Figure 5.1-17).

Table 5.1-13: Total number species and individual of understorey birds census belonging to each foraging-feeding guild in 30 years-old regenerated forest and the 50 years-old regenerated forest in Peninsular Malaysia. Feeding guild classification following Wells (1988) and Johns (1989).

Foraging-feeding guild		Number of species		Number of individuals		*P<.05*
		30 years-old	50 years-old	30 years-old	50 years-old	
Foliage gleaning insectivores	FGI	26	9	218	62	0.08
Bark gleaning insectivores	BGI	8	4	26	11	0.62
Sallying insectivores	SAI	13	8	70	29	0.07
Terrestrial insecivores	TI	6	6	122	23	0.00*
Terrestrial frugivores	TF	1	1	12	5	0.76
Arboreal insectivores	AI	3	0	5	0	0.17
Arboreal frugivores	AF	10	6	87	108	0.00*
Arboreal insectivores and frugivores	AIF	13	8	193	63	0.31
Insectivores and nectarivores	IN	7	6	250	68	0.02*
Carnivores	C	4	3	37	8	0.16
Seed	S	3	1	7	1	0.35
Foliage gleaning insectivores and carnivores	FGI/C	2	2	3	2	0.01*
Sallying insectivores and arboreal frugivores	SAI/AF	3	0	11	0	0.04*
Insectivores nectarivores and arboreal frugivores	IN/AF	1	0	2	0	0.38
Total		100	54	1043	380	

* = significant different (p<0.05) between 30 and 50 years-old regenerated forests. Calculated using chi-square test. Carnivores include piscivores and small arthropods consumers.

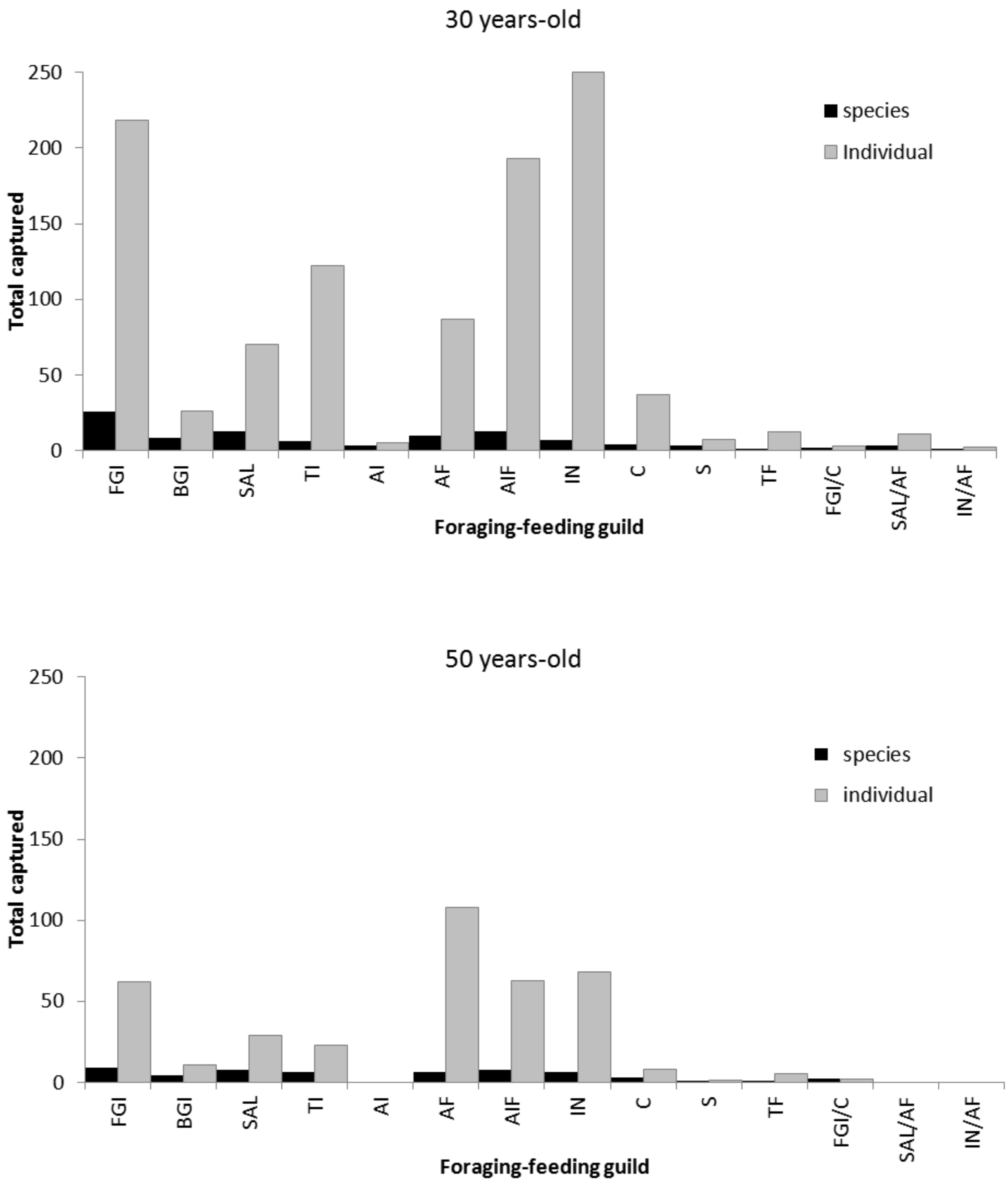


Figure 5.1-16: Total species and individuals captured based on foraging-feeding guilds of the understorey bird community in the 30 and 50 years-old regenerated forests, in Peninsular Malaysia.

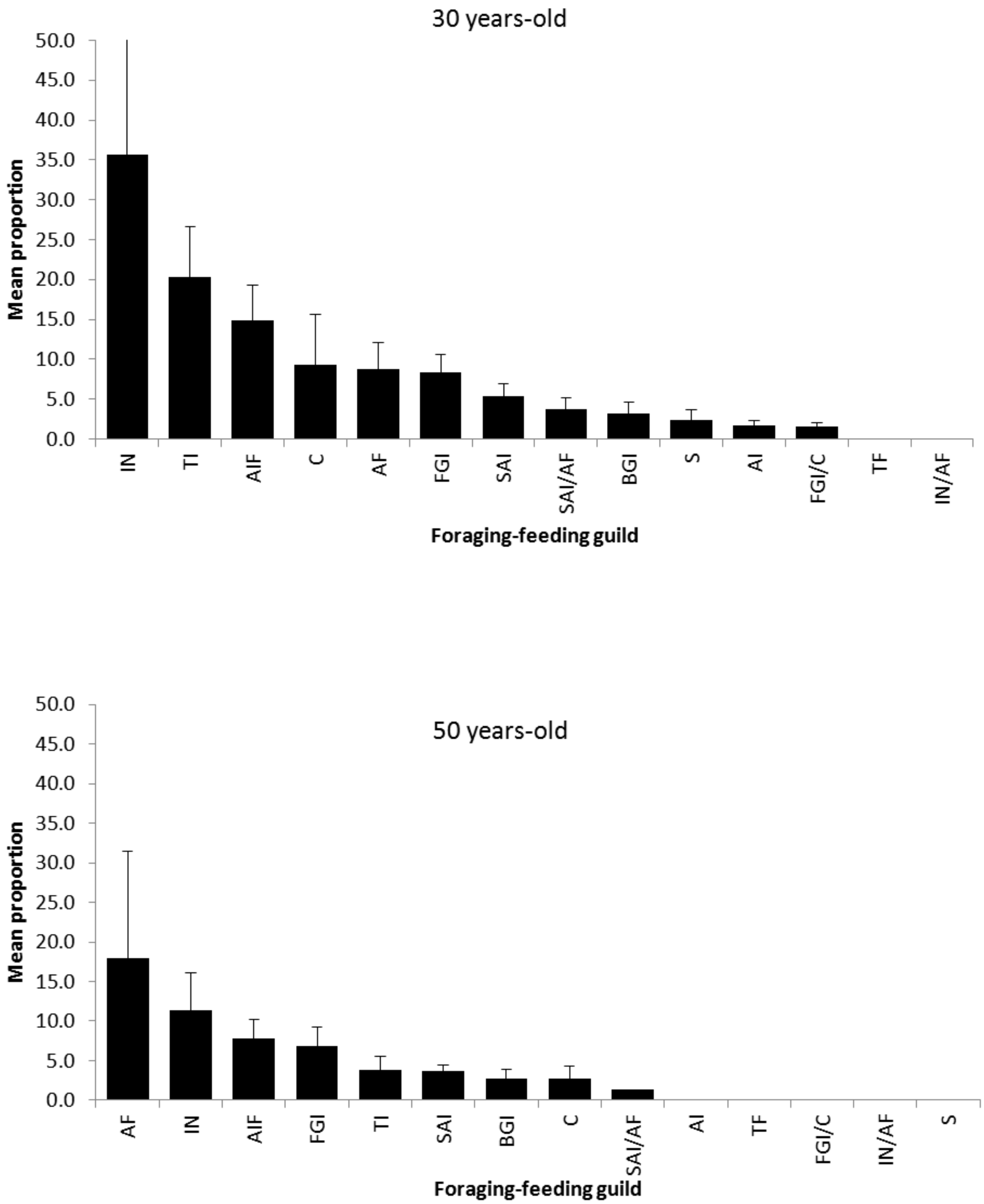


Figure 5.1-17: Mean proportion (number of individual per species) based on foraging-feeding guilds of the understorey bird community in 30 and 50 years-old regenerated forests, in Peninsular Malaysia.

5.3.3. Foraging guild

Four foraging guilds were detected in both study sites and this represented by arboreal foragers, sallying foragers, undergrowth foragers and generalist (which include more than one foraging techniques). Of these, two foraging guilds differ significantly in relative abundance between 30 years-old and 50 years-old regenerated forest (Figure 5.1-18).

Members of arboreal foragers (χ^2 = 6.44, p = 0.00) and undergrowth foragers (χ^2 = 4.64, p = 0.00) were significantly abundant in the 30 years-old regenerated forest than in 50 years-old regenerated forest.

More sallying (χ^2 = 0.10, p = 0.56) and generalist (χ^2 = 1.68, p = 0.14) birds were captured in 30 years-old regenerated forest. However, species relative abundance was not differ significantly with the 50 years-old regenerated forest.

In both regenerated forests, arboreal foragers had higher number of individual per species (mean proportion) followed by sallying and undergrowth foragers (Table 5.1-14 and Figure 5.1-19).

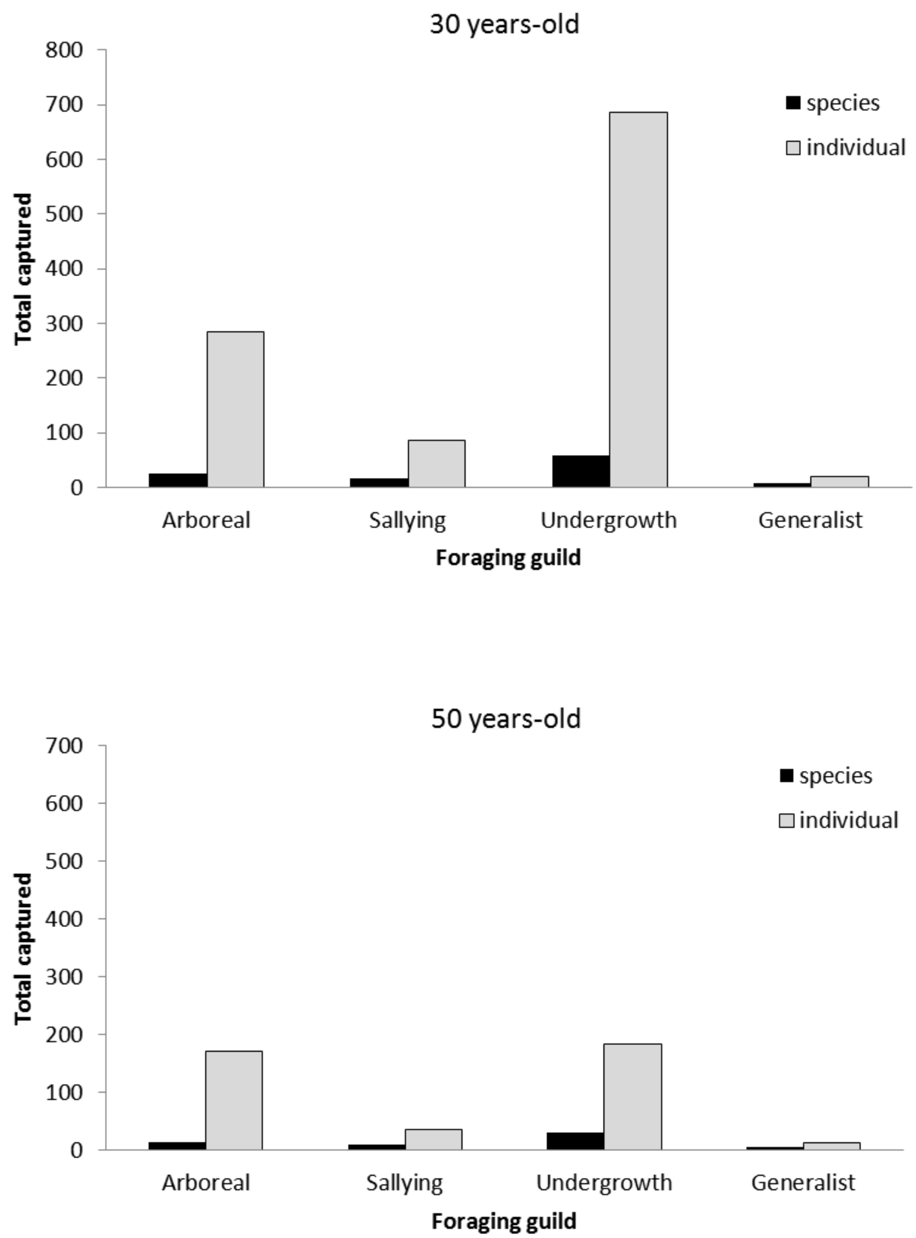


Figure 5.1-18: Distribution of species and individuals belong to four foraging techniques captured in 30 and 50 years-old regenerated forests. Undergrowth refer to understorey guilds

Table 5.1-14: Number of individuals per species belong to each feeding guild present in 30 and 50 years-old regenerated forests in Peninsular Malaysia.

Foraging guild	30 years-old			50 years-old			p
	No. of species	No. of individuals	Mean (SE)	No. of species	No. of individuals	Mean (SE)	
Arboreal	26	285	10.9 (2.7)	14	171	12.2 (5.8)	0.00*
Sallying	13	70	5.4 (1.6)	8	29	3.6 (0.9)	0.37
Undergrowth	55	672	11.9 (3.5)	30	178	5.9 (1.3)	0.00*
Generalist	6	16	2.7 (0.8)	2	2	1 (0.0)	0.23

* = significant difference between 30 and 50 year-old regenerated forest at $p<0.05$.
Arboreal (or canopy) includes insectivores, frugivores and combined insectivores and frugivores; **Undergrowth** (or understorey guilds) includes terrestrial insectivores, foliage and bark gleaning insectivores, seeds and carnivores (include piscivores); **Generalist** includes combined foliage-gleaning insectivores/carnivores, sallying insectivores/arboreal frugivores and combined insectivores/ nectarivores/arboreal frugivores.

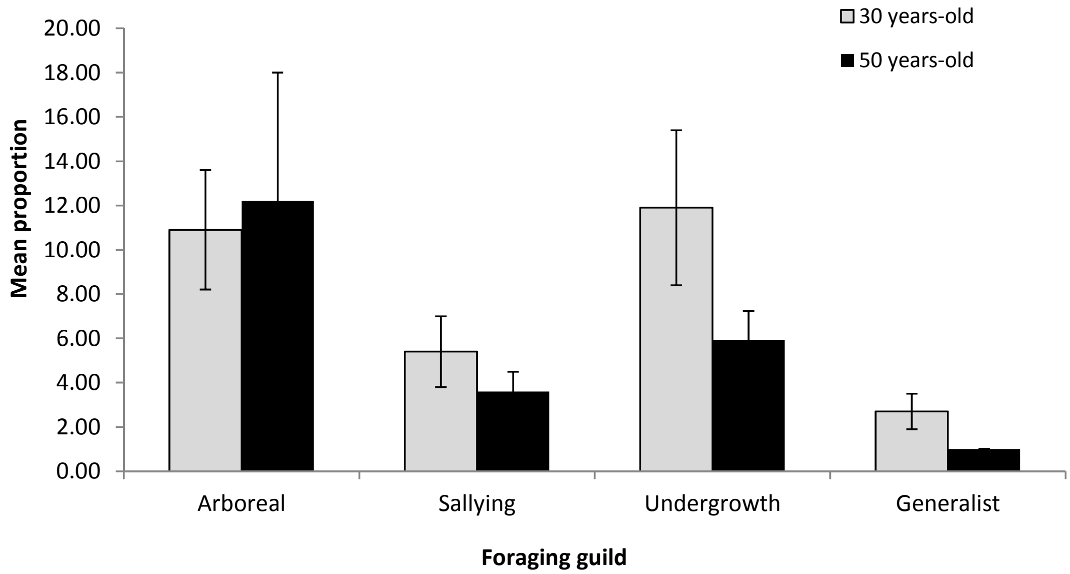


Figure 5.1-19: Number of individuals per species (mean proportion) of understory bird community inhabiting 30 and 50 years-old regenerated forests in Peninsular Malaysia.

6

DISCUSSION

This study had recorded 24% of Peninsular Malaysia bird species. The species numbers appeared to be higher in the 30 years-old regenerated forest (21%) compared to the 50 years-old regenerated forest (only 11%). However, study in the 30 years-old regenerated forest and 50 years-old regenerated forest only recorded less than half of the total species breeds in Peninsular Malaysia lowland rainforest (Wells & Medway 1976). The number of species captured was considered higher compared to other secondary growth forest patches such as Pasoh Forest Reserve (Wong 1986) and Sungai Lalang Forest Reserve (Zakaria et al. 2005).

However, species accumulation curve calculated in both regenerated forests begin to approach asymptotes after 12 stations were sampled. These indicated that the sampling effort has reached sufficient intensity where the sampling had succeeded in capturing most of the species present in both study areas (i.e. most of the resident species have been recorded).

The species estimation also indicates that the sampling efficiency reach above 50% in 50 years-old regenerated forest and 70% in 30 years-old regenerated forest throughout study period. This proved that current study had successfully recorded more bird species after 12 samplings and supports the effectiveness of the trapping method used.

As pointed out by Ramli et al. (2009) only half of the total species present in particular study area were successfully recorded by both mist-netting and observation techniques while another half of the total species are recorded either by direct observation (25%) or mist-netting technique only (25%). The ideas proposed by Ramli et al (2009) were proved by this study based on the sample-based rarefaction and accumulation curves; the number of species in both areas did reached an asymptote. This explained that the sampling on species occurrence at both study areas have reached the maximum number of species that could be detected and this also revealed that the current survey can be considered as quite extensive.

In addition, netting hours was not the major factor influence the total number of individual and species captured. This was proved by several samples in both study areas where more netting hours (680 hours) spent in the 50 year-old regenerated forest managed to capture only 17 species (27 individuals) whereby less netting hours (620) spent in 30 year-old regenerated forest able to capture more than 13 to 52 species. This also explained by the several samples in the 30 year-old regenerated forest same where same netting hours spent (620 hours) resulted in different number of species and individuals caught.

Total number of family captured in the 30 years-old regenerated forest (26 families) was almost similar to the Tekam Primary Forest Reserve (27 species) (Johns 1989) while it was higher than in Sungai Lalang primary forest reserve (15 families) (Zakaria et al. 2005). The latter study employed mist-netting as sampling method, similar to current study (Table 6.1-1). More bird families were recorded by previous study in Bekok and Belumut primary forest reserves due both studies are using point count method (Peh et al. 2005). In the light of this, the 30 years-old regenerated forest is able to support most of the families occurred in primary forest reserve. This further explained that regenerated forest which had been undergoes regeneration process after been selectively logged for more than 25 years is able to provide habitat with adequate food resources, nesting and roosting sites to most of the bird families occurred in Peninsular Malaysia (55 families of forest dependent species). However, of total families of forest dependent species occurred in Peninsular Malaysia, only 29% was successfully recorded in the 50 years-old regenerated forest.

Table 6.1-1: List of understorey bird present in primary forest reserve conducted by previous and current studies in Peninsular Malaysia.

Family	Number of species					
	Primary Forest				Regenerated Forest (current study)	
	TFR	SLFR	BekFR	BelFR	30 years	50 years
Acanthizidae	0	0	1	0	0	0
Aegithinidae	6	0	2	2	0	0
Alcedinidae	3	4	5	5	4	4
Campephagidae	6	0	5	5	0	0
Capitonidae	4	0	6	6	1	0
Chloropseidae	0	0	3	3	1	0
Columbidae	3	1	6	3	1	1
Corvidae	2	0	3	3	1	0
Cuculidae	8	3	10	10	4	2
Dicaeidae	3	0	8	7	3	4
Dicruridae	3	2	2	2	1	0
Eupetidae	0	0	1	1	0	0
Eurylaimidae	2	1	5	5	4	2
Irenidae	0	0	1	1	1	0
Laniidae	1	1	0	0	1	1
Meropidae	2	0	1	1	1	1
Monarchidae	0	0	4	4	4	2
Muscicapidae	12	8	5	4	12	9
Nectariniidae	7	3	9	9	7	6
Oriolidae	2	0	1	1	1	0
Paridae	1	0	0	1	0	0
Phasianidae	1	0	5	5	0	0
Picidae	10	5	11	10	8	4
Pittidae	1	1	3	2	0	0
Psittagidae	2	0	3	3	0	0
Pycnonotidae	13	7	14	15	17	10
Rhipiduridae	0	0	1	1	1	0
Sittidae	1	0	1	1	0	0
Strigiformes	0	2	0	0	0	0
Sturnidae	2	0	1	1	0	0
Sylviidae	5	1	1	1	9	4
Timalidae	18	13	24	23	14	7
Trogonidae	5	0	4	4	3	0
Turdidae	7	4	4	3	4	4
Estrildidae	0	0	0	0	3	1
Zosteropidae	0	0	0	0	2	0
Total species	130	58	157	142	109*	62*

TFR = Tekam Forest Reserve in Negeri Sembilan by Johns (1989), SLFR = Sungai Lalang Forest Reserve in Selangor by Zakaria et al. (2005), BekFR and BelFR = Bekok Forest Reserve and Belumut Forest Reserve in Johore by Peh et al. (2005). Understorey bird species only considered in this list. *Total species include migratory bird.

The family Pycnonotidae and Nectariniidae formed considerable proportion (>50%) of total species captured in both areas. This finding was in-line with previous study which indicated that the Pycnonotidae and Nectariniidae (which mostly comprised of secondary or colonizing species such as bulbuls and spiderhunters) appeared to be the most abundant in secondary growth forest (Zakaria et al. 2005). Little Spiderhunter was the most abundant species in the 30 years-old regenerated forest while Orange bellied Flowerpecker was found dominated the 50 years-old regenerated forest. The Little Spiderhunter generally not joining larger mix species flocks instead foraging in single or pairs and most often found near flowering plants where they obtain nectar produced by undergrowth plant such as wild banana and gingers (pers. obs.). Although this species had a broad range of distribution, it commonly used lowland rainforest and sometimes extend its territory into montane forest. It was commonly found in secondary forest but also frequenting forest fringe or wooded area of primary forest (Ramli et al. 2009).

Other birds that commonly found dominated the 30 years-old regenerated forest and the 50 years-old regenerated forest are secondary growth species which usually related to open area or edge. These were Yellow-breasted Flowerpecker, Orange-bellied Flowerpecker, Grey-breasted Spiderhunter and Purple-naped Sunbird. These species are known as comensal species which highly associated with disturbed areas (Ramli et al. 2009). They preferred open canopy and tolerant to smaller trees. Many secondary or edge specialist species rely on small fruits produced by undergrowth plants/shrubs and vines at lower canopy (Peh et al. 2005; Edwards et al. 2009). Nevertheless leaf litter trapped on tangled vines provides food sources for insectivorous bird and nesting sites for secondary growth specialists. This is the reason why more edge and secondary growth specialist was easily trapped in the nets.

Meanwhile Black-headed Bulbul (from pycnonotidae family) appeared to be abundant in both regenerated forests. This colonizing secondary species generally occurred in small flocks (comprising six to eight individuals) and feeds mainly on insect, small fruit and berries produced by secondary growth plants, vines or shrubs (Edwards et al. 2009). This species are highly adaptable to inhabit logged forest because of their ability to switch their diets from frugivores to insectivores whenever the fruits are scarce or vice versa (Zakaria et al. 2005; Edwards et al. 2009). In addition, opportunistic species like bulbuls and spiderhunters would always benefited from the logging activities which eliminating most of the species that fed on insects on the forest floor or glean on bark (such as thrushes, pittas, flycatchers and babblers).

Of 22 commoner species defined as intolerant to recently logged forest (i.e. selectively logged) by Johns (1986), eight and seven species was present in the 50 and the 30 years-old regenerated forests respectively. Of these, five species occurred in both regenerated forests. These are Oriental dwarf Kingfisher (*Ceyx arithacus*), Banded Kingfisher (*Lacedo pulchella*), Rufous Piculet (*Sasia abnormis*) Grey-headed Babbler (*Stachyris poliocephala*) and Crimson-breasted Flowerpecker (*Prionochilus percussus*). Two species were recorded in 30 years-old regenerated forest only. These are Spotted-Fantail (*Rhipidura perlata*) and Fluffy-back tit Babbler (*Macronus ptilosus*) The remaining three species were present only in the 50 years-old regenerated forest. These were Grey-headed Flycatcher (*Culicapa ceylonensis*) Mugimaki Flycatcher (*Ficedula mugimaki*) and Rufous-collared Kingfisher (*Actenoides concreta*).

Although the occurrence of this intolerant species to recently logged forest was represented by only a few individuals, their presence in both regenerated forests are important indicator to species conservation status. It is important to note that the timing of forest regeneration after logging plays an important role in determining forest inhabitant. The existence of intolerant species in 30 and the 50 years-old regenerated forests proved that the forests almost regain its degree structure of old growth forest after being left undisturbed for more than 25 years. This conservation had provided better habitat aligned with the needs of every bird species where food and microclimate in the understorey are the two most concerned and highly related with the survival of understorey bird.

Johns (1989) had pointed out that the physiological consideration such as heat and water balances are much more important in determining the variation of understorey bird than local food abundance. Undeniable, water balance and heat which highly regulated the understorey humidity being the ultimate factors determine the successful of regeneration process in the understorey. Gaps that have been created after logging process allowed the light to penetrate the forest floor and automatically reduce the moisture and dry out debris/leaf litter/ where most of terrestrial feeders forage. This drying effect increased with increased light penetration and possibly halting or slowing the regeneration (Styring and Zakaria 2004). Balance in water and heat (humidity) play as secondary factor that induced the plant or trees to regrow and regenerate.

A number of the bird species inhabiting unlogged/primary forest had been captured in regenerated forests but at a lesser abundances (Table 6.1-1). Natural regeneration process re-creates the cool and humid microclimate, typical characteristic of understorey level of primary forest, and this allows colonization of understorey bird. Species such as pittas have been observed many times in the 50 years-old regenerated forest. Usually forest regeneration process would allow habitat modification into old growth forest structure. Research by Dent & Wright (2009) and Ramli et al. (2009) discovered that secondary forest would play an important role in conserving the biodiversity particularly when old growth forests are located nearby. Peh et al. (2006) also concluded that relatively high forest species richness were presence in degraded habitat which associated with the nearby primary forest fragments that serve as a source habitat.

Several primary forest babblers such as Short-tailed Babbler and Black capped Babbler was abundantly caught in the 30 years-old regenerated forest. These solitary species breed in Peninsular Malaysia, Singapore, Thailand, the island of Sumatera and Borneo and can be found in tropical moist lowland forest. They typically forage on forest floor (grasp on leaf-litter) on a variety of insects including termites, ants and beetles. The species have successfully recolonized the regenerated forest due to the presence of undisturbed forest patches and regeneration of the forest canopy and sparse ground cover.

In addition the foliage gleaning babblers such as Grey throated Babbler, Grey headed Babbler and Striped tit Babbler were abundantly caught in both regenerated forests (refer Appendix 2 and 3 for status and distribution). These species mainly forage at understorey level on tree branches and vines. Understorey guild was reported exhibited little pronounced preference by microhabitat changes (Cleary et al. 2007). Fluffy backed-tit Babbler which inhabiting subtropical or tropical moist lowland forests and subtropical or tropical swamps (Robson 2000) and classified by IUCN (2006) as threatened due to habitat loss also recorded in the study areas especially in the 30 years-old regenerated forest but at lesser abundances. This species is one of the few babblers that seem to increase in abundance in logged forest due to species preference of dense vine and thick herbaceous growth associated with gaps.

Several migrant and resident/migrant) primary forest species were caught in both regenerated forests though at lesser abundances. These species were represented by Crow-billed Drongo (*Dicrurus annectans*), Japanese-paradise flycatcher (*Terpsiphone atrocaudata*) and Brown-chested Flycatcher (*Rhinomyias brunneata*).

While the resident/migrant and uncommon species was represented by Hill blue Flycatcher (*Cyornis banyumas*). All species were categorized as sallying insectivores' and tend to use old growth regenerated logged forest for two reasons, either for food searching or just passing by from pocket of unlogged forest nearby. This primary forest species generally occupy the canopy level and searching for insects that glean on the canopy trees and generally intolerant to secondary growth and dense ground cover.

In addition, both regenerated forests experience the disturbance caused by logging activity. In this sense, the secondary growth that was left untouched for a longer period (more than 25 years) had allowed forest to regenerate to maximum (Peh et al. 2005). This will attracts more primary forest species and increase the ratio of total diversity to secondary or colonizing species as well as edge species (Peh et al. 2005; Zakaria et al. 2005; Ramli et al. 2009). This finding was supported by Zakaria et al. (2005) which indicated logging activity will change species composition through retaining some species but reduction of others. The presence of several red listed species in the 30 and the 50 years-old regenerated forests provides strong evidence on the ability of both areas in providing valuable habitat and sufficient resources. The presence of Near-Threatened (NT) species like Japanese-paradise Flycatcher (*Terpsiphone atrocaudata*) and Vulnerable (V) species such as Brown-chested Jungle Flycatcher (*Rhinomyias brunneata*) proved this.

Several woodpeckers species were also recorded in the 30 and the 50 years-old regenerated forests (Table 6.1-2). This bark gleaning insectivorous species group is often considered sensitive or prone to disturbance create by logging since most species dig/excavating nest cavities in trees and many of them forage on dead wood (Johns 1989; Lambert & Collar 2002; Styring and Zakaria 2004). Eight woodpecker's species were caught in the 30 years-old regenerated forest while four species were captured in the 50 years-old regenerated forest. Previous studies reported that, only four woodpeckers species were recorded in Pasir Raja and Endau Rompin Forest Reserves and only two species were captured in Berembun and Tekam Forest Reserves (ups. data.). However previous study via observation method conducted in primary forest at Pasoh Forest Reserve (Styring and Ickes 2001) and Sungai Lalang Forest Reserve (Styring and Zakaria 2004) successfully recorded 12 woodpeckers' species in each forest.

On the other hand, a few of primary forest woodpeckers' species were caught in both regenerated forests. Species such as Buff necked Woodpecker (*Meiglyptes tukki*) was recorded in both study areas but at lesser abundances. It generally forages on termites or ants and most commonly present in unlogged forest but uncommonly sighted recently logged forest (1 to 5 years). The presence of this species is a good indicator about canopy intensity where species are highly associated with extensive/sufficient canopy cover.

Species such as Orange backed Woodpecker (*Reinwardtipicus validus*) which forages on snags is more frequently detected in primary forest (Styring and Ickes 2001). The occurrence of this species in the 30 years-old regenerated forest indicate a good sign for the conservation ability of the regenerated forest. The presence of this species indicate the restoration of sufficient canopy cover even at certain parts of the regenerated forest which further provide availability of preferred food. Other species that are commonly frequenting unlogged forest were Crimson winged Woodpecker (*Picus puniceus*). This species forages on a variety of microhabitats but preferred the medium or large dead wood and snags. Therefore it also can be used as important indicators of forest physical condition. Their presence is associated with high canopy covers which absent from recently logged forest. The combination of food availability and sufficient canopy cover were probably the most important factors in determining abundances of this species in particular area (Styring and Zakaria 2004).

Rufous Woodpecker (*Celeus brachyurus*) and Maroon Woodpecker (*Blythipicus rubiginosus*) are commonly associated with recently logged forest and rarely sighted in unlogged forest. Rufous woodpecker generally forages in a variety of microhabitats and prefer large gaps or open areas while the latter species forages primarily on dead wood and prefer dense understorey (Styring and Ickes 2001; Styring and Zakaria 2004). Rufous Piculet (*Sasia abnormis*) appear to be moderately common in both study areas but was recorded at lesser abundance in unlogged forest by previous studies (Styring and Ickes 2001; Styring and Zakaria 2004). This species generally associated with dense understorey and usually frequenting on small tree branches of undergrowth plants, small lianas, bamboo and rattan (Styring and Zakaria 2004). However it will avoid the sparse and homogenous understorey which usually being the character of unlogged and older regenerated forests.

The presence of several woodpeckers' species in both study areas provides important clue about bird conservation in both regenerated forests. Both study areas seem capable in providing habitat for sensitive species which have very limited niche. Further conservation plan should consider maintaining large tree and snags in regenerated forest/older logged forest as these will provide important microhabitat and feeding or nesting sites for woodpeckers.

Table 6.1-2: List of 16 species of woodpeckers recorded in primary and regenerated forests in Peninsular Malaysia. The occurrence of species in three primary forests and 40 years-old regenerated forest was carried out by other researchers.

Species	Frequency of occurrence					
	Primary forest			Regenerated forest		
	PFR	SLFR	PRFR	30 years	40 years	50 years
Bamboo Woodpecker *Gecinulus viridis*	0	0	0	1	0	1
Banded Woodpecker *Picus miniceaus*	2	1	0	0	4	0
Buff-necked Woodpecker *Meiglyptes tukki*	5	19	1	6	4	3
Buff-rumped Woodpecker *Meiglyptes tristis*	14	4	0	0	4	0
Checker-throated Woodpecker *Picus mentalis*	1	24	1	1	20	0
Common Goldenback *Dinopium javanense*	0	0	0	0	4	0
Crimson-winged Woodpecker *Picus puniceus*	7	14	0	2	12	0
Great-slaty Woodpecker *Mulleripicus pulverulentus*	1	5	0	0	0	0
Grey-capped Woodpecker *Picoides canicapillus*	0	0	0	0	0	0
Grey-and buff Woodpecker *Hemicircus concretus*	0	9	0	0	1	0
Maroon Woodpecker *Blythipicus rubiginosus*	4	8	1	2	1	0
Olive-backed Woodpecker *Dinopium rafflessi*	2	0	0	0	0	0
Orange-backed Woodpecker *Reinwardtipicus validus*	15	14	1	1	6	0
Rufous Piculet *Sasia abnormis*	1	4	0	12	0	6
Rufous Woodpecker *Celeus branchyurus*	4	7	0	1	2	1
White-bellied Woodpecker *Dryocopus javanensis*	6	14	0	0	1	0

PFR and 40 years regenerated forest = Pasoh Forest Reserve by Styring and Ickes (2001), SLFR = Sungai Lalang Forest Reserve by Styring and Zakaria (2004), PRFR = Pasir Raja Forest Reserve (Unpublished data), 30 years and 50 years regenerated forest = current study.

Logging altered forest structured and adversely affect forest-dependent birds. These species are fully dependent on forest for foraging sites, nesting and roosting sites and they rarely forage outside the forest (Newmark 2006). Disturbance created by logging appeared to affect bird species composition with respect to feeding guild. This has been proved in numerous studies in Southeast Asia including Malaysia (Johns 1986; Wong 1986; Johns 1989; Lambert 1992; Johns 1996; Lambert and Collar 2002; Zakaria et al. 2005; Edwards et al. 2009 and Edwards et al. 2011).

Results from current study indicate insectivorous birds dominated both study areas, followed by generalist and frugivorous while carnivorous (include picivorous) and seed eaters/granivorous were the least bird present. Insectivorous comprised mostly of understorey bird species as well as bird that feed at canopy level. Species that are restricted to canopy level, terrestrial or ground dwelling are highly affected by disturbance created by logging process (Newmark 2006; Claery et al. 2007).

A considerable proportion of terrestrial insectivores (TI) were caught in 30 and the 50 years-old regenerated forests. Several species comprised of babblers (family Timalidae), shamas, robins and forktails each (family Turdidae). The most abundant species caught were represented by Short tailed Babbler, Black capped Babbler, White rumped Shama and Chestnut naped Forktail. The first two species were present abundantly in the 30 years-old regenerated forest while the last two species were equally recorded in both regenerated forests (Table 5.1-12). The guild similarity suggested that resources present in both study areas are similar to that available in unlogged forest. Both study areas comprised of an area that have less undergrowth vegetation (i.e. shrubs) with sparse ground cover. In addition, the forest also has patches of sufficient canopy cover to maintain humidity at understorey level. The area that have more open canopy usually allow more light penetration to the forest ground caused dry out of debris/leaf-litters that support numbers of insects and arthropods

(Wong 1986; Johns 1989; Peh et al. 2005; Zakaria et al. 2005; Newmark 2006; Cleary et al. 2007). In this sense the terrestrial insectivores can easily forage on the ground by grasp on the leaf-litter on the forest floor.

Newmark (2006) had concluded that terrestrial insectivores were the most negatively affected birds by logging and suggested that longer recovery time is needed for terrestrial insectivores in slightly and moderately disturbed forest. Evidences collected from current study proved that the forest which has undergone recovery process for 30 years or more are able to support more terrestrial insectivore species. The recovery process is more effective if unlogged forest pockets are located nearby. This unlogged pockets the sources for species conservation (Peh at al. 2005; 2006).

Of terrestrial insectivores present in Pasoh primary forest (PFR), only two species were caught in both study areas. These are Short tailed Babbler and Chestnut naped Forktail. Although the total numbers of terrestrial insectivore's species in regenerated forests and PFR are almost equal, species composition are markedly different (Table 6.1-3). Several terrestrial insectivores inhabiting PFR were featured by Garnet Pitta (*Pitta granatina*), Large-wren Babbler (*Napothera macrodactyla*), Orange headed Thrush (*Zoothera citrina*) and Short toed Coucal (*Centropus rectunguis*). These species forage on leaf-litter insects and arthropods of the forest floor which strictly required sparse undergrowth vegetation/forest and sheltered forest floor to maintain humidity (Johns 1986).

Current study was unable to capture terrestrial-dependent species such as wren-babblers and pittas. Both species are relatively rare and difficult to locate, even in primary forest (Peh et al. 2005). Two species of pittas, i.e. Banded Pitta or Blue winged Pitta have been sighted outside the study period dwelling 50 years-old regenerated forest for several times. Both species were reported to decline following logging (Johns

1989; Johns 1996). Evidence from current study proved that none of this species were recorded in 30 years-old regenerated forest although the most efficient method to record this species was applied (mist-netting method) (Johns 1996). Peh et al. (2005) also fail to record any cryptic species (including terrestrial babblers and pittas) in logged forest using direct observation method. Theoretically longer time is needed (more than 50 years) for recolonizing and re-establishment of this species in selectively logged forest due to species required large sheltered understorey sparse forest floor.

Foliage-gleaning insectivores were the most abundant species group caught in both study areas. All species in this group forage at understorey level. Most of the species caught were represented by several species of babblers from (family Timalidae), warblers, prinias and tailorbirds (family Sylviidae). Understorey foliage-gleaning insectivores were least affected by logging-induced disturbance. Therefore, these species are strongly associated with logged forest as have been reported previously (Johns 1989 and 1996; Newmark 2006; Cleary et al. 2007). This group was responding to the marked increase of forest undergrowth. The foliage-gleaning babblers such as Striped tit Babbler have been reported to increase following logging (Johns 1989). A remarkable abundance of foliage-gleaning insectivores indicated that the resources were widely spread in both study areas and least affected by microhabitat changes. However sallying insectivore's birds are among the most abundant group captured in both study areas. Majority of this species was represented by flycatchers which favor tall undisturbed forest and more open understorey (Thiollay 1992). The presence of this species with remarkable abundance indicated that food resources are widely available and extensively distributed.

Terrestrial frugivores remain as the smallest guild caught in both study areas. This finding is in line with previous studies in primary forest (Wong 1986; Johns 1989). Green winged Pigeon (*Chalcophaps indica*) is representing this group for both study areas. This bird often forages a variety of fallen fruits/seed on the forest floor and spending little time on trees except when roosting. Most of these birds were caught in 30 years-old regenerated forest indicated that the population is re-establishing due to availability of resources. Unfortunately this species is facing pressure from hunting (due to easy accessibility created after logging) to both study areas. From personal observation, this species frequently used skid trails to forage and is highly tolerable to least canopy cover or light.

Table 6.1-3: Distribution of the selected bird guild of birds inhabiting regenerated forests (current study) and primary forest (previous studies).

Feeding-Foraging guild	Number of species			
	Regenerated Forest		Primary Forest	
	30 years-old	50 years-old	TFR	PFR
Terrestrial insectivores (TI)	6	6	8	6
Bark Gleaning Insectivores (BGI)	8	4	11	6
Foliage Gleaning Insectivores (FGI)	26	9	37	25
Sallying insectivores (Sal)	13	8	15	12
Insectivores and Nectarivores (IN)	7	6	7	8
Arboreal Insectivores and Frugivores (AIF)	13	8	22	10
Terrestrial Frugivores (TF)	1	1	1	1
Arboreal Frugivores (AF)	10	6	12	3

TFR = Tekam Forest Reserve in Pahang by Johns (1989) and PFR = Pasoh Forest Reserve in Negeri Sembilan by Wong (1986). Both forest reserves located in Peninsular Malaysia. Species from family Accipitridae, Falconidae, Tytonidae, Strigidae, Caprimulgidae, Apopidae and Hemifrocnidae that observed in primary forest were excluded in this list.

Although previous studies reported that arboreal frugivores are the most affected group by logging process, it was abundantly caught in both study areas of regenerated forest. Example of this species include Green broadbill (*Calyptomena viridis*), Asian-fairy Bluebird (*Irena puella*) Red-throated Barbet (*Megalaima mystacophanos*) and several species of flowepeckers (family Dicaeidae). These species are seriously affected by forest disturbance since it strictly feed on fruits produced by trees at canopy level and do not eat fruits produces by undergrowth, vines or climbers (Peh et al. 2005; Yap et al. 2007; Edwards et al. 2009). Thus species in this group have larger home range in order to acquire enough resources to fulfill their diets. This was supported by the absence of *Calyptomena viridis* and *Eurylaimus javanicus* in recaptured list. This species are also intolerant to smaller trees which primarily structured by secondary growth vegetation. The presence of this group in both study areas indicates that the restoration and development of the forest canopy and distribution of fruits are highly available at the canopy level.

The vegetation and species diversity in both study areas of regenerated forest may recovered and probably regain a condition close to natural state although it may take longer time (Dunn 2004). Dent and Wright (2009) reported that the re-establishment of slow-growing and shade-tolerant tree species might takes 20 years. On the other hand, the recovery and restoration of forest condition such as the closure of forest canopy and high rates of leaf-litter extremely encourage the recovery process. The restoration of woody plant close to unlogged forest might take 80 years (Dent and Wright 2009). After 30 and 50 years of forest regeneration, both study areas are able to provide variety of microhabitats which supports many species due to the availability of various food resources, nesting and roosting sites. The presence of sensitive species, primary forest species and threatened species are a good indicator to the forests health as the forest healed from the disturbance created by logging over time.

7

CONCLUSION

It has been long recognized that bird like many other animals often move nomadically in response to disturbance in the availability of food and microclimate conditions (Borghesio and Laiolo 2004). Birds are sensitive to environmental changes in pursuing their survival. Any changes in distribution of food supply at regional level will directly affect bird activity pattern such as breeding and movement (Avery 1980; Sodhi 2002; Ramli et al. 2009). It has been widely studied that distribution of food influenced bird population and ecology (Wong 1986; Stutchbury and Morton 2001; Borghesio and Laiolo 2004; Ramli 2004). This study had focus on the effect of microhabitat changes on the understorey bird diversity and species composition. Habitat modification alters resource availability in the forest. This is an ultimate factor in determining bird distribution and assemblages (Lambert 1989 and Sodhi 2002). Unfortunately only a handful of study has been conducted at local level especially in Malaysia. Although overall bird abundance does not show remarkable changes in Peninsular Malaysia, differences do exist at species level.

Bird diversity somehow changes following disturbance created by human. Changes in forest physical environment lead to the changes in species composition. Forest habitat provides food and shelter for all forest dependent species. Therefore a slight change by human will affect forest ecosystem. As a result, it is useless to conserve bird without conserving their natural habitat. To efficiently conserve biodiversity, all plants and other wildlife taxa should be taken into consideration. More details research need to be conducted on changes of species diversity with respect to species composition in different phases of regenerated forest. To provide more comprehensive information, this can be done by extending bird sampling period and increase the number study sites with different phases/ages of regeneration process.

Alhamdulilah…