

# ASSESSING THE EFFECTS OF LOGGING ACTIVITIES ON AVIAN RICHNESS AND DIVERSITY IN DIFFERENT AGED POST-HARVESTED HILL DIPTEROCARP TROPICAL RAINFOREST OF MALAYSIA

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## ABSTRACT

Logging activities have encroached into the hill dipterocarp tropical rainforest area since the lowland dipterocarp forests have decreased in size. Hill dipterocarp tropical rainforest is rich in habitat diversity and provide a variety of resources for avian species such as food, habitat and shelter. Therefore it is important to examine the logging effects of hill dipterocarp rainforest on avian species. We compared the avian richness and diversity in different aged post-harvested hill dipterocarp tropical rainforest at the Berkelah Hill Dipterocarp Rainforest Reserve in Maran, Pahang, West Malaysia using mist-netting method. We captured a total of 1908 individuals representing 86 species and 29 families (i.e., 18.55% from two years post-harvested forest, 25.10% from ten years post-harvested, 23.90% from twenty years post-harvested and 32.44% from thirty five years post-harvested forests). Forty nine species were caught in two years and ten years, 55 species in twenty years and 59 species in thirty five years' post-harvested forest. Seventeen species were common in all four types of forest. Pycnonotidae, Timaliidae and Nectariniidae were the most dominant families in all types of post-harvested hill dipterocarp tropical rainforest. Diversity analysis indicated that the bird species in twenty years post-harvested hill dipterocarp rainforest was most diverse (i.e., Fisher's Alpha Diversity Index; 16.34) and evenly distributed (i.e., McIntosh Evenness index E; 0.933) as compared to two years, ten years and thirty five years post-harvested forest. However, thirty five years post-harvested forest was richest in avian species (i.e., Margalef's Richness index  $R_1$ ; 9.02) as compared to other post-harvested forest. The findings of this study revealed that logging and recovery process may affects on avian distribution and diversity. However, these effects may vary from species to species.

**Keywords:** Birds, Rainforest, Mist-Netting, Post-Harvesting, Species Richness

## 1. INTRODUCTION

Malaysia is blessed with a variety of forest types such as lowland dipterocarp forest, hill dipterocarp forest, upper-hill dipterocarp forest, oak-laurel forest, montane ericaceous forest, peat swamp forest, mangrove forests. Malaysian hill forests are dominated by trees of dipterocarpaceae which grows from 300 m to an altitude of 900 m. The significant feature of hill dipterocarp forest is the presence of Seraya

(*Shorea* sp.) large size trees which most frequently grows on hill ridges with prolific undergrowth of *Eugeissona tristis* (Bertam palm) and *Oncosperma horridum* (Thorny palm tree). These forests are the most diverse in vegetation structure and composition that supported a diversity of wildlife species especially avian which directly or indirectly depend on the forests for survival.

Malaysia is rich in vegetation diversity and are home of 742 bird species which directly or indirectly use the forest

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habitats. Despite of rich in avian diversity, 50% of tropical forests have been destroyed and degraded at alarming rate due to anthropogenic activities such as urbanization, conversion into agricultural fields (Fitzherbert *et al.*, 2008; Edwards *et al.*, 2011; Fisher *et al.*, 2011) and logging activities (Fahrig, 2003; Castelletta *et al.*, 2005; 2000; Clark *et al.*, 2009). It has been reported that protected forest areas of Southeast Asia has been fragmented and reduced due to deforestation (Laurance, 1999; Curran *et al.*, 2004; DeFries *et al.*, 2005).

Forest logging may results in habitat fragmentation which can lead to reductions in nutrient availability and habitat for a wide array of wildlife species (Chaves *et al.*, 2012). Forest logging directly or indirectly reduced the habitat suitability of forest fauna (Potts, 2011) such as butterflies and mammals (Brook *et al.*, 2003; Sehgal, 2010) and monkeys (Collins, 2008). Due to logging, the forest becomes fragmented, more irregular and isolated (Echeverria *et al.*, 2007) which affects on distribution, richness and diversity of avian species (McCarthy, 2012). In addition, logging also modified plant species diversity, vegetation composition and structure (Hill and Curran, 2003; Arroyo-Rodriguez and Mandujano, 2006) that may alter or reduced food resources and habitat suitability (Arroyo-Rodriguez and Mandujano, 2006). It has been assessed that the forest area loss and degradation has seriously affected the community structures of wildlife

species i.e., some of them become extinct while others are endangered and vulnerable due to habitat loss and degradation (Koh *et al.*, 2004; Cardillo *et al.*, 2005; Brook *et al.*, 2006; Sodhi and Brook, 2006).

Currently, the information regarding the effects of hill dipterocarp tropical forest logging on wildlife species is not sufficient and it needed more investigation. Hence, it is extremely important to study the avian richness and diversity in different aged post-harvested hill dipterocarp rainforest in order to understand the effects of logging and recovery process on avian community for future direction and conservation activities. In this study, we examine the avian richness and diversity in two years, ten years, twenty years and thirty years post-harvested forests.

## 2. MATERIALS AND METHODS

### 2.1. Study Area

This study is located at the Berkelah Hill Dipterocarp Rainforest Reserve in Maran, Pahang, West Malaysia (2° 57' 43" N, 101° 41' 47" E) (Fig. 1). This hill dipterocarp rainforest consists of mixture of undisturbed primary forest and different aged post-harvested forests. We selected two years, ten years, twenty years and thirty five years post-harvested forest areas within the forest reserve.

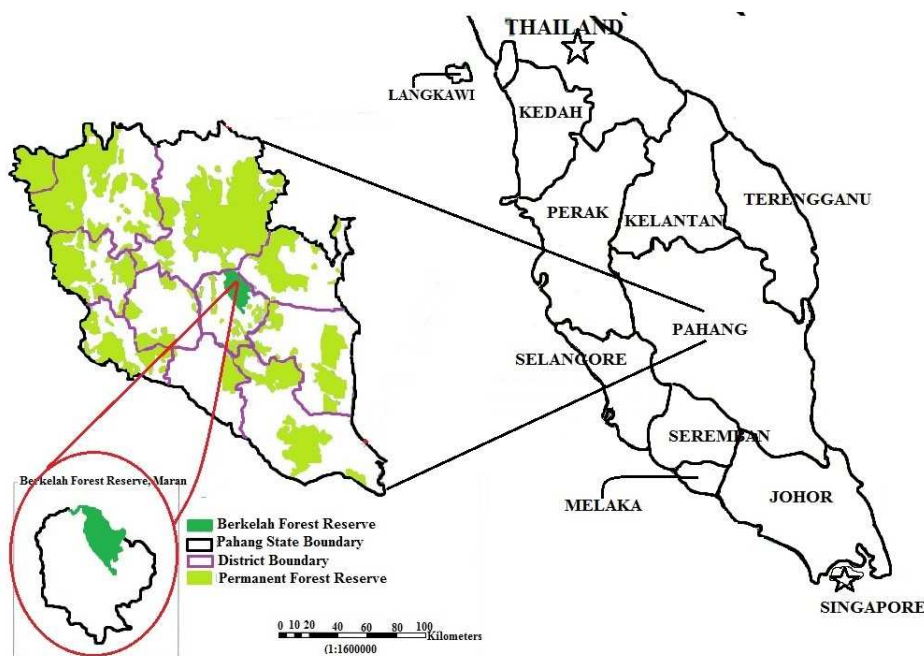


Fig. 1. Location map of Berkelah forest reserve Maran, Pahang, West Malaysia

## 2.2. Bird Surveys

Bird species were caught using ten mist-nets (14×4 m with 3 pockets) in two years, ten years, twenty years and thirty years post-harvested forests. The netting was done for a total of 3,084 h or 257 days from January 2011 to December, 2012. The nets were stretched between two bamboo poles that were fixed into soil. The lower end of the net was kept at the ground to capture all type of birds at different locations. The nets were opened at 0700-1900 h and placed for three days in the same sampling site before transferred to new site. Three days netting was sufficient to capture most of the birds as after three days, birds may become familiar with the mist nets (Robbins *et al.*, 1997). The nets were monitored hourly and each individual bird captured was tagged with a numbered aluminium ring on the right tarsus and photographed before they were released (Robson, 2002; Ralph and Dunn, 2004; Rajpar and Zakaria, 2010; 2012).

## 3. DATA ANALYSIS

### 3.1. Relative Abundance (%)

Relative abundance refers to the number of individuals of a particular species as percent of the total capture in both areas. We estimated relative abundances for each species using average detection values calculated by dividing the total number of a species captured at different aged post-harvested hill dipterocarp tropical rainforest. The relative abundance (%) of bird species was estimated using the following expression:

$$\text{Relative abundance} = n / N \times 100$$

Where:

n = The number of a particular captured bird species while  
N = The total number captured over all species

### 3.2. Bird Diversity Indices

Avian species diversity, species richness and species evenness in different aged post-harvested hill dipterocarp tropical rainforests were analyzed using Community Analysis Package Software (CAP, Version 4.0) (Henderson and Seaby, 2007).

The Fisher's alpha for each forest type was calculated using the following equation:

$$S = a * \ln(l + n / a)$$

Where:

S = Number of taxa  
n = Number of individuals and  
a = Fisher's alpha

Margalef's richness index was calculated using the following equation:

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

Where:

S = Number of taxa and  
N = Number of individuals

McIntosh evenness index E was calculated using the following equation:

$$McE = [N - \sqrt{(\sum ni^2)}] / [N - (N / \sqrt{S})]$$

Where:

McE = McIntosh evenness index  
n<sub>i</sub> = Number of individuals belonging to i species,  
S = Total number of species and  
N = Total number of individuals

### 3.3. Significant Difference Among Different Aged Post-Harvested Forest Habitats

A One-Way Analysis of Variance (ANOVA) and Tukey's (HSD) test (Analytical Software, version 8.1) by (McGraw-Hill, 2008) was conducted in order to investigate the difference in bird richness and habitat characteristics between primary and logged hill dipterocarp tropical rainforest.

## 4. RESULTS

### 4.1. Bird Species Composition with Relative Abundance in Different Aged Post-Harvested Hill Dipterocarp Tropical Rainforests

Overall, mist-netting method captured a total of 1908 bird individuals representing 86 bird species and 29 families (i.e., 18.55% from two years post-harvested forest, 25.10% from ten years post-harvested, 23.90% from twenty years post-harvested and 32.44% from thirty five years' post-harvested forests). Seventeen bird species were captured from all types of forest while 49 bird species (each) were caught in two years and ten years post-harvested forest, 55 bird species were caught in twenty years post-harvested forest and 59 bird species were caught in thirty five years post-harvested forest.

#### 4.2. Bird Species Composition with Relative Abundance in Two Years Post-Harvested Forest

A total of 354 bird individuals were captured (i.e., 18.55%) from two years post-harvested hill dipterocarp rainforest representing 49 bird species and 21 families. Three bird species i.e., *Arachnothera longirostra*-Little Spiderhunter (4.09%), *Pycnonotus simplex*-Cream-vented Bulbul and *P. erythroptalmus*-Spectacled Bulbul (1.15% each) were the most common bird species in the two years post-harvested forest. On the contrary, four bird species i.e., *Ixos malaccensis*-Streaked Bulbul, *Copsychus malabaricus*-White-rumped Shama, *Harpactes diardii*-Diard's Trogon and *Eurylaimus javanicus*-Banded Broadbill were least abundant (each 0.05%- captured only once; **Table 1**).

#### 4.3. Bird Species Composition with Relative Abundance in Ten Years Post-Harvested Forest

In the ten years post-harvested hill dipterocarp rainforest a total of 479 bird individuals of 49 species representing 18 families were captured. The results indicated that *A. longirostra*-Little Spiderhunter (4.93%), *Alophoixus phaeocephalus*-Yellow-bellied Bulbul (1.26%) and *Hypogramma hypogrammicum*-Purple-naped Sunbird (1.10%) were the most abundant bird species in ten years post-harvested forest. In contrast, four species namely *Pitta guajan*-Banded Pitta, *Picus miniacus*-Banded Woodpecker, *Platylophus galericulatus*-Crested Jay and *Batrachostomus stellatus*-Gould's Frogmouth were considered as the rarest (each 0.05%) (**Table 1**).

#### 4.4. Bird Species Composition with Relative Abundance in Twenty Years Post-Harvested Forest

Likewise, a total of 456 bird individuals belonging to 55 species and 21 families were captured from twenty years post-harvested hill dipterocarp rainforest. Four bird species namely; *A. longirostra*-Little Spiderhunter (2.25%), *H. hypogrammicum*-Purple-naped Sunbird (1.42%), *Meiglyptes tukki*-Buff-necked Woodpecker (1.26%) and *Malacopteron magnum*-Rufous-crowned Babbler (1.15%) were the most abundant bird species captured with higher number of individuals. In addition, 13 bird species such as *Malacopteron cinereum*-Scaly-crowned Babbler, *Pycnonotus bruunus*-Redeye Bulbul, *Iole olivacea*-Buff-vented Bulbul, *P. cyaniventris*-Grey-

bellied Bulbul, *Chloropsis cyanopogon*-Lesser Green Leafbird, *Lonchura leucogastra*-White-bellied Munia, *Malacocincla malaccensis*-Short-tailed Babbler, *B. stellatus*-Gould's Frogmouth, *Anthreptes simplex*-Plain Sunbird, *Calormphus fuliginosus*-Brown Barbet, *Prionochilus percussus*-Crimson-breasted Flowerpecker, *A. magna*-Streaked Spiderhunter and *Eumyias thalassinus*-Verditer Flycatcher were considered as the rarest bird species in twenty year post-harvested forest i.e., (i.e., 0.05% each) (**Table 1**).

#### 4.5. Bird Species Composition with Relative Abundance in Thirty Five Years Post-Harvested Forest

A total of 619 bird individuals belong to 59 bird species and 21 families were caught from thirty five year post-harvested hill dipterocarp rainforest. The results indicate that *M. magnum*-Rufous-crowned Babbler (2.88%), *Malacopteron magnirostre*-Moustached Babbler (1.83%), *H. hypogrammicum*-Purple-naped Sunbird (1.78%), *A. phaeocephalus*-Yellow-bellied Bulbul (1.68%) and *Meiglyptes tukki*-Buff-necked Woodpecker (1.62%) were the most dominant bird species in thirty years post-harvested hill dipterocarp rainforest. On contrary, eight bird species i.e., *Trichastoma rostratum*-White-chested Babbler, *P. miniacus*-Banded Woodpecker, *A. simplex*-Plain Sunbird, *Lacedo pulchella*-Banded Kingfisher, *Enicurus ruficapillus*-Chestnut-naped Forktail, *Muscicapella hodgsoni*-Pygmy Blue Flycatcher, *Otus rufescens*-Reddish Scops Owl and *Ficedula zanthopygia*-Yellow-rumped Flycatcher were the rarest (i.e., 0.05% each) in thirty year years post-harvested forest (**Table 1**).

#### 4.6. Comparison of Bird Species Composition in Different Aged Post-Harvested Forests

Twenty seven bird species were commonly captured from two years and twenty years post-harvested forest, However, twenty two bird species were sampled only in a two years post-harvested forest which were absent in ten years post-harvested forest. Likewise, twenty two bird species were captured in ten years post-harvested forest but absent in a two years post-harvested forest. In addition, 29 bird species were commonly detected in two years post harvested and twenty years post-harvested forest. However, 20 bird species were recorded only in a two year post harvested forest which were absent in twenty years post-harvested forest. Similarly, 26 bird species were captured only in twenty years post-harvested forest and were absent in a two year post-harvested forest (**Table 1**).

**Table 1.** Bird species composition with relative abundance in different aged post-harvested hill dipterocarp tropical rainforest at Berkelah Forest Reserve Maran, Pahang, West Malaysia

Family	Scientific name	Common name	Two years post-harvested forest		Ten years post-harvested forest		Ten years post-harvested forest		Thirty five years post-harvested forest	
			No of captures	%	No of captures	%	No of captures	%	No of captures	%
Nectariniidae	<i>Arachnothera longirostra</i>	Little Spiderhunter	78	4.09	94	4.93	43	2.25	28	1.47
Pycnonotidae	<i>Pycnonotus simplex</i>	Cream-vented Bulbul	22	1.15	16	0.84	12	0.63	9	0.47
Pycnonotidae	<i>Pycnonotus erythroptalmos</i>	Spectacled Bulbul	22	1.15	14	0.73	11	0.58	8	0.42
Meropidae	<i>Merops viridis</i>	Blue-throated Bee-eater	19	0.84	14	0.73	11	0.58	3	0.16
Timaliidae	<i>Malacopteron cinereum</i>	Scaly-crowned Babbler	16	0.84	17	0.89	1	0.05	0	0.00
Pycnonotidae	<i>Pycnonotus briuneus</i>	Redeye Bulbul	13	0.68	9	0.47	1	0.05	3	0.16
Timaliidae	<i>Malacopteron magnum</i>	Rufous-crowned Babbler	11	0.58	17	0.89	22	1.15	55	2.88
Nectariniidae	<i>Arachnothera modesta</i>	Grey-breasted Spiderhunter	11	0.58	8	0.42	7	0.37	12	0.63
Turdidae	<i>Copsychus saularis</i>	Oriental Magpie Robin	9	0.47	6	0.31	4	0.21	0	0.00
Alcedinidae	<i>Alcedo meninting</i>	Blue-eared Kingfisher	9	0.47	4	0.21	3	0.16	2	0.10
Cisticolidae	<i>Orthotomus atrogularis</i>	Dark-necked Tailorbird	9	0.47	0	0.00	0	0.00	0	0.00
Eurylaimidae	<i>Cymbirhynchus macrorhynchos</i>	Black-and-red Broadbill	8	0.42	5	0.26	2	0.10	0	0.00
Cuculidae	<i>Cacomantis merulinus</i>	Plaintive Cuckoo	8	0.42	5	0.26	0	0.00	0	0.00
Picidae	<i>Meiglyptes tukki</i>	Buff-necked Woodpecker	7	0.37	19	1.00	24	1.26	31	1.62
Laniidae	<i>Lanius cristatus</i>	Brown Shrike	7	0.37	0	0.00	0	0.00	0	0.00
Timaliidae	<i>Stachyris erythroptera</i>	Chestnut-winged Babbler	6	0.31	9	0.47	12	0.63	19	1.00
Pycnonotidae	<i>Pycnonotus finalysoni</i>	Stripe-throated Bulbul	6	0.31	4	0.21	2	0.10	0	0.00
Hirundinidae	<i>Hirundo rustica</i>	Barn Swallow	6	0.31	0	0.00	0	0.00	0	0.00
Nectariniidae	<i>Arachnothera flavigaster</i>	Spectacled Spiderhunter	6	0.31	0	0.00	0	0.00	0	0.00
Aegithinidae	<i>Aegithina viridissima</i>	Green Iora	5	0.26	0	0.00	0	0.00	0	0.00
Laniidae	<i>Lanius tigrinus</i>	Tiger Shrike	5	0.26	0	0.00	0	0.00	0	0.00
Pycnonotidae	<i>Alophoixus phaeocephalus</i>	Yellow-bellied Bulbul	4	0.21	24	1.26	19	1.00	32	1.68
Turdidae	<i>Luscinia cyne</i>	Siberian Blue Robin	4	0.21	15	0.79	7	0.37	11	0.58
Muscicapidae	<i>Philentoma pyrhoptera</i>	Rufous-winged Philentoma	4	0.21	9	0.47	14	0.73	17	0.89
Pycnonotidae	<i>Tricholestes criniger</i>	Hairy-backed Bulbul	4	0.21	9	0.47	16	0.84	24	1.26
Pycnonotidae	<i>Pycnonotus eutilotus</i>	Puff-backed Bulbul	4	0.21	2	0.10	0	0.00	0	0.00
Oriolidae	<i>Oriolus xanthonotus</i>	Dark-throated Oriole	4	0.21	0	0.00	2	0.10	2	0.10
Muscicapidae	<i>Muscicapa dauurica</i>	Asian Brown Flycatcher	4	0.21	0	0.00	0	0.00	0	0.00
Campephagidae	<i>Hemipus hirundinaceus</i>	Black-winged Flycatcher Shrike	4	0.21	0	0.00	0	0.00	0	0.00
Timaliidae	<i>Trichastoma rostratum</i>	White-chested Babbler	3	0.16	7	0.37	0	0.00	1	0.05
Timaliidae	<i>Macronus ptilosus</i>	Fluffy-backed Tit-Babbler	3	0.16	2	0.10	0	0.00	0	0.00
Chloropseidae	<i>Chloropsis cochinchinensis</i>	Blue-winged Leafbird	3	0.16	0	0.00	0	0.00	0	0.00
Pycnonotidae	<i>Alophoixus ochraceus</i>	Ochraceous Bulbul	2	0.10	11	0.58	16	0.84	19	1.00
Eurylaimidae	<i>Calyptomena viridis</i>	Green Broadbill	2	0.10	10	0.52	14	0.73	21	1.10
Pycnonotidae	<i>Pycnonotus plumosus</i>	Olive-winged Bulbul	2	0.10	0	0.00	6	0.31	0	0.00
Cisticolidae	<i>Prinia rufescens</i>	Rufescent Prinia	2	0.10	0	0.00	2	0.10	0	0.00
Pycnonotidae	<i>Iole olivacea</i>	Buff-vented Bulbul	2	0.10	0	0.00	1	0.05	0	0.00
Pycnonotidae	<i>Pycnonotus cyaniventris</i>	Grey-bellied Bulbul	2	0.10	0	0.00	1	0.05	0	0.00
Chloropseidae	<i>Chloropsis cyanopogon</i>	Lesser Green Leafbird	2	0.10	0	0.00	1	0.05	0	0.00
Estrildidae	<i>Lonchura leucogastra</i>	White-bellied Munia	2	0.10	0	0.00	1	0.05	0	0.00
Falconidae	<i>Microhierax fringillarius</i>	Black-thighed Falconet	2	0.10	0	0.00	0	0.00	0	0.00
Timaliidae	<i>Malacocincla sepiaria</i>	Horsfield's Babbler	2	0.10	0	0.00	0	0.00	2	0.10
Muscicapidae	<i>Ficedula mugimaki</i>	Mugimaki Flycatcher	2	0.10	0	0.00	0	0.00	0	0.00
Dicaeidae	<i>Dicaeum trigonostigma</i>	Orange-bellied Flowerpecker	2	0.10	0	0.00	0	0.00	0	0.00
Timaliidae	<i>Macronus gularis</i>	Pin-striped Tit-Babbler	2	0.10	0	0.00	0	0.00	0	0.00
Pycnonotidae	<i>Ixos malaccensis</i>	Streaked Bulbul	1	0.05	9	0.47	14	0.73	19	1.00
Muscicapidae	<i>Copsychus malabaricus</i>	White-rumped Shama	1	0.05	8	0.42	17	0.89	22	1.15
Trogonidae	<i>Harpactes diardii</i>	Diard's Trogon	1	0.05	2	0.10	0	0.00	0	0.00
Eurylaimidae	<i>Eurylaimus javanicus</i>	Banded Broadbill	1	0.05	0	0.00	0	0.00	4	0.21
Nectariniidae	<i>Hypogramma hypogrammicum</i>	Purple-naped Sunbird	0	0.00	21	1.10	27	1.42	34	1.78
Timaliidae	<i>Malacopteron magnirostre</i>	Moustached Babbler	0	0.00	16	0.84	23	1.21	35	1.83
Alcedinidae	<i>Ceyx rufidorsa</i>	Rufous-backed Kingfisher	0	0.00	11	0.58	15	0.79	20	1.05
Monarchidae	<i>Terpsiphone paradisi</i>	Asian Paradise Flycatcher	0	0.00	9	0.47	8	0.42	11	0.58
Timaliidae	<i>Stachyris poliocephala</i>	Grey-headed Babbler	0	0.00	9	0.47	18	0.94	28	1.47
Alcedinidae	<i>Alcedo euryzona</i>	Blue-banded Kingfisher	0	0.00	7	0.37	0	0.00	2	0.10
Irenidae	<i>Irena puella</i>	Asian Fairy-bluebird	0	0.00	6	0.31	2	0.10	2	0.10
Timaliidae	<i>Malacocincla malaccensis</i>	Short-tailed Babbler	0	0.00	6	0.31	1	0.05	3	0.16
Timaliidae	<i>Stachyris nigricollis</i>	Black-throated Babbler	0	0.00	6	0.31	10	0.52	13	0.68
Rhipuduridae	<i>Rhipidura perlata</i>	Spotted Fantail	0	0.00	6	0.31	3	0.16	5	0.26
Monarchidae	<i>Hypothymis azurea</i>	Black-naped Monarch	0	0.00	5	0.26	8	0.42	13	0.68

**Table 1.** Continue

Timaliidae	<i>Trichastoma bicolor</i>	Ferruginous Babbler	0	0.00	5	0.26	6	0.31	10	0.52
Muscicapidae	<i>Rhinomyias umbratilis</i>	Grey-chested Jungle Flycatcher	0	0.00	5	0.26	12	0.63	16	0.84
Timaliidae	<i>Pellorneum capistratum</i>	Black-capped Babbler	0	0.00	4	0.21	6	0.31	14	0.73
Picidae	<i>Sasia abnormis</i>	Rufous Piculet	0	0.00	3	0.16	2	0.10	3	0.16
Picidae	<i>Picus mentalis</i>	Checker-throated Woodpecker	0	0.00	3	0.16	6	0.31	8	0.42
Alcedinidae	<i>Alcedo atthis</i>	Common Kingfisher	0	0.00	2	0.10	4	0.21	7	0.37
Picidae	<i>Blythipicus rubiginosus</i>	Maroon Woodpecker	0	0.00	2	0.10	3	0.16	4	0.21
Pittidae	<i>Pitta guajana</i>	Banded Pitta	0	0.00	1	0.05	2	0.10	3	0.16
Picidae	<i>Picus miniaceus</i>	Banded Woodpecker	0	0.00	1	0.05	0	0.00	1	0.05
Corvidae	<i>Platylophus galericulatus</i>	Crested Jay	0	0.00	1	0.05	3	0.16	5	0.26
Podargidae	<i>Batrachostomus stellatus</i>	Gould's Frogmouth	0	0.00	1	0.05	1	0.05	3	0.16
Alcedinidae	<i>Ceyx erithaca</i>	Black-backed Kingfisher	0	0.00	0	0.00	5	0.26	6	0.31
Nectariniidae	<i>Anthreptes simplex</i>	Plain Sunbird	0	0.00	0	0.00	1	0.05	1	0.05
Alcedinidae	<i>Lacedo pulchella</i>	Banded Kingfisher	0	0.00	0	0.00	0	0.00	1	0.05
Pycnonotidae	<i>Pycnonotus melanoleucos</i>	Black-and-white Bulbul	0	0.00	0	0.00	0	0.00	2	0.10
Ramphastidae	<i>Calormphus fuliginosus</i>	Brown Barbet	0	0.00	0	0.00	1	0.05	2	0.10
Muscicapidae	<i>Enicurus ruficapillus</i>	Chestnut-naped Forktail	0	0.00	0	0.00	0	0.00	1	0.05
Timaliidae	<i>Stachyris maculata</i>	Chestnut-rumped Babbler	0	0.00	0	0.00	0	0.00	8	0.42
Trogonidae	<i>Harpactes orrhophaeus</i>	Cinnamon-rumped Trogon	0	0.00	0	0.00	0	0.00	2	0.10
Dicaeidae	<i>Prionochilus percussus</i>	Crimson-breasted Flowerpecker	0	0.00	0	0.00	1	0.03	0	16.00
Muscicapidae	<i>Muscicapella hodgsoni</i>	Pygmy Blue Flycatcher	0	0.00	0	0.00	0	0.00	1	0.05
Strigidae	<i>Otus rufescens</i>	Reddish Scops Owl	0	0.00	0	0.00	0	0.00	1	0.05
Timaliidae	<i>Malacopteron affine</i>	Sooty-capped Babbler	0	0.00	0	0.00	0	0.00	2	0.10
Nectariniidae	<i>Arachnothera magna</i>	Streaked Spiderhunter	0	0.00	0	0.00	1	0.05	2	0.10
Muscicapidae	<i>Eumyias thalassinus</i>	Verditer Flycatcher	0	0.00	0	0.00	1	0.05	2	0.10
Muscicapidae	<i>Ficedula zanthopygia</i>	Yellow-rumped Flycatcher	0	0.00	0	0.00	0	0.00	1	0.05
Total			354		479		456		619	

**Table 2.** Diversity indices of bird species in different post-harvested hill dipterocarp tropical rainforest at Berkelah Reserve Maran, Pahang, West Malaysia

Habitat	Fisher's alpha diversity index	Margalef's richness index R <sub>1</sub>	McIntosh evenness index E
Two years post-harvested hill Dipterocarp tropical rainforest	15.43	8.18	0.855
Ten years post-harvested hill Dipterocarp tropical rainforest	13.66	7.78	0.884
Twenty years post-harvested hill Dipterocarp tropical rainforest	16.34	8.82	0.933
Thirty five years post-harvested hill Dipterocarp tropical rainforest	16.02	9.02	0.929

The comparison results of two year post-harvested forest and thirty five year post-harvested forest indicated that 22 bird species were common, 27 bird species only used two year post-harvested forest and avoided to use thirty year post-harvested forest. Likewise, 37 bird species only utilized thirty five year post-harvested forest and totally avoided to visit two year post-harvested forest. The comparative results of ten year post-harvested and twenty years post-harvested forest showed that 42 bird species were common which utilized both types of habitats and 7 bird species only prefer to utilize ten year post-harvested forest and avoided twenty years post-harvested forest. Similarly, 13 bird species only utilized twenty years post-harvested forest and avoided ten year post-harvested forest (**Table 1**).

In addition, the comparison results of twenty years and thirty five year post-harvested forest revealed that 45 bird species commonly utilized both types of post-harvested forests. However, 10 bird species only used twenty years post-harvested forest and were absent in thirty five year post-harvested forest. Likewise, 14 bird species only captured in thirty year post-harvested forest and were absent in twenty years post-harvested forest (**Table 1**).

Furthermore, the comparison results of the One-way ANOVA and Tukey's (HSD) test revealed that mean avian relative abundance of two years post-harvested hill dipterocarp rainforest (4.12±1.07), ten years post-harvested hill dipterocarp rainforest (5.57±1.66), twenty years post-harvested hill dipterocarp rainforest (5.30±1.51) and thirty five years post-harvested hill

dipterocarp rainforest ( $7.20 \pm 1.47$ ) was not significantly different from each other ( $F_{3, 343} = 1.42, p < 0.05$ ).

#### 4.7. Comparison of Bird Diversity Indices in Different Aged Post-Harvested Forests

The diversity analysis indicated that the bird species in the twenty years post-harvested hill dipterocarp rainforest was most diverse (i.e., Fisher's Alpha Diversity Index; 16.34) and most evenly distributed (i.e., McIntosh Evenness index E; 0.933) as compared to the two years, twenty years and thirty five years post-harvested forests. However, thirty years post-harvested forest was richest in avian species (i.e., Margalef's Richness index  $R_1$ ; 9.02) as compared to other post-harvested forest (Table 2).

### 5. DISCUSSION

The hill dipterocarp tropical rainforest is rich in habitat diversity that offers a variety of resources for avian species such as food, habitat and shelter. Birds are bio-indicators of forest ecosystem health i.e., they are more conspicuous, easy to study and are closely associated with vegetation structure. Birds may exploit different types of vegetated areas (Gill, 2006) and occupy a wide range of habitats. The recording of 49 bird species (each) from two years and ten years post-harvested hill dipterocarp tropical rainforest, 55 bird species from twenty years post-harvested forest and 59 bird species from thirty five years' post-harvested hill dipterocarp tropical rainforest indicated that forest logging activities and recovery process may affect avian distribution, richness and diversity directly and indirectly.

This also indicated that the thirty five years post-harvested hill dipterocarp forest has replaced the loss of vegetation and harboured a wide array of avian species richness and diversity as compared two years, ten years and twenty years post-harvested hill dipterocarp rainforest. It has been reported that many aspects of the forest especially the vegetation structure, composition and food resources have recovered (Chazdon *et al.*, 2007; Dent and Wright, 2009) that may accommodate higher avian richness and diversity (Ellwood *et al.*, 2002; Ellwood and Foster, 2004). Food resources distribution may regulate population of bird species (Wright *et al.*, 1999; Johnson and Sherry, 2001) and fruit abundance influences the species composition and foraging behaviour of fruit eating birds (Moegenburg and Levey, 2003). For example; fruit eating birds always concentrated where fruit occurs abundantly because their diet consists of more

than 50% fruits (Kinnard *et al.*, 1996; Sherman and Eason, 1998; Malizia, 2001; Renton, 2001).

The capturing of higher number of sunbirds, spider-hunters and bulbuls at the two years post-harvested forest indicated that forest logging is a major determinant factors which effects on the richness and distribution of these bird species by modifying vegetation structure and composition (McShea and Rappole, 2000) and these bird species are resilience to disturbance. These bird species are considered as open country birds and utilized open area such as parks, gardens and plantations. (Campbell *et al.*, 2007; Costello *et al.*, 2000) reported that songbird species diversity increased in harvested areas i.e., they often prefers interior edge, forest gaps and logged areas (Moorman *et al.*, 2002; Gram *et al.*, 2003; King and DeGraaf, 2004). This might be that an open areas may provide suitable habitat and foraging sites for them (Gram *et al.*, 2003; Campbell *et al.*, 2007). Selective forest logging leads to the increase of temperature and decrease relative humidity (Johns, 1988; Jackson *et al.*, 2002). Opening gaps enhance shrub vegetation which frequently bears diverse flowers and fruits which is a major diet of these bird species. (Doyon *et al.*, 2005; Pers, 2000) and (Robinson and Robinson, 1999) stated that logging of trees cause gaps which enhance the growth of shrubs (understorey vegetation) which attract the understorey bird species such as warbler.

Likewise, capturing of good numbers of babbler species at the thirty five years post-harvested forest showed that these bird species are less resilient to disturbance and are habitat specialists. This indicated that bird richness and diversity increase with recovery after logging. Tree diversity and richness affect the food availability and accessibility that ultimately influence bird distribution and diversity. The variation in habitat selection might be due to differences in foraging behaviour and niches i.e., some inhabit canopy to hunt on flies or forage on fruits (barbets). The heterogeneity of vegetation affects productivity (Belisle *et al.*, 2001; Ishikawa *et al.*, 2003; Currie *et al.*, 2004) that potentially offer more niches for avian species through providing a wide range of resources such as food, suitable shelter and nesting sites and also safe roosting sites. Avian richness is associated with the abundance, distribution and diversity of food resources (Marquez *et al.*, 2004; Novotny *et al.*, 2006) and directly associated with vegetation composition and structure (Seymour and Simmons, 2008;

Lindenmayer *et al.*, 2010). The difference in vegetation structure and food resources can attract bird species (Campbell *et al.*, 2007; Holmes and Pitt, 2007) that prefers large areas of young sapling, regenerating and early successional vegetation (Costello *et al.*, 2000; DeGraaf and Yamasaki, 2003).

Overall, the results of this study indicated that bird communities are dynamic and may change in relation to recovery process after logging such as logging creates canopy gaps by removing trees, after logging during recovery process changes in vegetation structure may occur over time which affects the avian richness and diversity through affecting food resources (Cambell *et al.* 2007) i.e., increased nest predation and brood parasitism (Rodewald, 2002; Thompson *et al.*, 2002; Thompson and Burhans, 2003; Lemelin *et al.*, 2007). During the recovery process many plant species become mature and start flowering and fruiting which attract insects (bees, wasps, butterflies, moths, beetles and flies) which is a major diet of avian species. Invertebrate communities of the tropical rain forest are highly diverse and their distribution and richness is associated with a diversity of vegetation structure and composition such as foliage, flowers, fruits, barks (Small and Pringle, 2010; Batista Matos *et al.*, 2013; Peters *et al.*, 2013). Silva and Brandao (2010) reported that invertebrate density strongly associated with vegetation structure and may vary at spatial scales of a few meters. Invertebrates are an important component of the food web in the forest ecosystem.

## 6. CONCLUSION

The findings of this study revealed that logging and recovery process may affect on avian distribution and diversity. However, these effects may vary from species to species. As the forest regenerates and recovers the vegetation characteristics after logging may accommodate the higher bird species diversity and richness depending upon the rate of recovery process.

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