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

Rajpar, M.N. and M. Zakaria

Department of Recreation and Ecotourism, Faculty of Forestry, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia

Received 2014-01-23; Revised 2014-04-30; Accepted 2014-07-15

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; 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 Eugeisonna 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
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.
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:

\[
\text{Relative abundance} = \frac{n}{N} \times 100
\]

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:

\[
S = a \times \ln(l + n / a)
\]

Where:
- \( S \) = Number of taxa
- \( n \) = Number of individuals
- \( a \) = Fisher's alpha

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

\[
R_i = \frac{(S - l)}{\ln(n)}
\]

Where:
- \( S \) = Number of taxa and
- \( N \) = Number of individuals

McIntosh evenness index \( E \) was calculated using the following equation:

\[
McE = \left[ N - \sqrt{(\sum n_i^2 / N - N / \sqrt{S})} \right]
\]

Where:
- \( McE \) = McIntosh evenness index
- \( n_i \) = Number of individuals belonging to \( i \) species,
- \( S \) = Total number of species
- \( N \) = 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. erythrophalmus-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 diardi-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%), Alopoxius 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 miniaceus-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 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 magnirostre-Moustached 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 bruneus-Redeye Bulbul, Iole olivacea-Buff-vented Bulbul, P. cyaniventris-Grey-bellied Bulbul, Chloropsis cyanopogon-Lesser Green Leafbird, Lonchura leucoatra-White-bellied Munia, Malacocincla malaccensis-Short-tailed Babbler, B. stellatus-Gould’s Frogmouth, Anthreptes simplex-Plain Sunbird, Calormopus 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. magnirostre-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. miniaceus-Banded Woodpecker, A. simplex-Plain Sunbird, Lacedo pulchella-Banded Kingfisher, Enicurus ruficapillus-Chestnut-naped Forktail, Muscapella hodgsoni-Pygmy Blue Flycatcher, Otus rufescens-Reddish Scope 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>
<thead>
<tr>
<th>Family</th>
<th>Scientific name</th>
<th>Common name</th>
<th>Two years post-harvested forest</th>
<th>Ten years post-harvested forest</th>
<th>Ten years post-harvested forest</th>
<th>Thirty five years post-harvested forest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>No of captures</td>
<td>%</td>
<td>No of captures</td>
<td>%</td>
</tr>
<tr>
<td>Nectarinidae</td>
<td>Hypothymis azurea</td>
<td>Black-naped Monarch</td>
<td>0</td>
<td>0.00</td>
<td>5</td>
<td>0.26</td>
</tr>
</tbody>
</table>
Table 1. Contiine

<table>
<thead>
<tr>
<th>Family</th>
<th>Species</th>
<th>Subspecies/Local Name</th>
<th>Frequency</th>
<th>Abundance</th>
<th>Dominance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timaliidae</td>
<td><em>Trichastoma bicolor</em></td>
<td>Ferruginous Babbler</td>
<td>0 0.00</td>
<td>5 0.26</td>
<td>6 0.31</td>
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<tr>
<td>Muscicapidae</td>
<td><em>Rhinomyias umbratilis</em></td>
<td>Grey-chested Jungle Flycatcher</td>
<td>0 0.00</td>
<td>5 0.26</td>
<td>12 0.63</td>
</tr>
<tr>
<td>Timaliidae</td>
<td><em>Pellorneum capistratum</em></td>
<td>Black-capped Babbler</td>
<td>0 0.00</td>
<td>4 0.21</td>
<td>6 0.31</td>
</tr>
<tr>
<td>Picidae</td>
<td><em>Sasia abnormis</em></td>
<td>Rufous Piculet</td>
<td>0 0.00</td>
<td>3 0.16</td>
<td>2 0.10</td>
</tr>
<tr>
<td>Picidae</td>
<td><em>Picus mentalis</em></td>
<td>Checker-throated Woodpecker</td>
<td>0 0.00</td>
<td>3 0.16</td>
<td>6 0.31</td>
</tr>
<tr>
<td>Alcedinidae</td>
<td><em>Alcedo athel</em></td>
<td>Common Kingfisher</td>
<td>0 0.00</td>
<td>2 0.10</td>
<td>14 0.73</td>
</tr>
<tr>
<td>Picidae</td>
<td><em>Blythiceps rufogularis</em></td>
<td>Maroon Woodpecker</td>
<td>0 0.00</td>
<td>2 0.10</td>
<td>3 0.16</td>
</tr>
<tr>
<td>Pittidae</td>
<td><em>Pitta guajana</em></td>
<td>Banded Pitta</td>
<td>0 0.00</td>
<td>1 0.05</td>
<td>2 0.10</td>
</tr>
<tr>
<td>Picidae</td>
<td><em>Picus miniacus</em></td>
<td>Banded Woodpecker</td>
<td>0 0.00</td>
<td>1 0.05</td>
<td>0 0.00</td>
</tr>
<tr>
<td>Corvidae</td>
<td><em>Platyptala galericulata</em></td>
<td>Crested Jay</td>
<td>0 0.00</td>
<td>1 0.05</td>
<td>3 0.16</td>
</tr>
<tr>
<td>Podargidae</td>
<td><em>Batrachostomus stellatus</em></td>
<td>Gould’s Frogmouth</td>
<td>0 0.00</td>
<td>1 0.05</td>
<td>3 0.16</td>
</tr>
<tr>
<td>Alcedinidae</td>
<td><em>Cerys erithaca</em></td>
<td>Black-backed Kingfisher</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>5 0.26</td>
</tr>
<tr>
<td>Nectariniida</td>
<td><em>Anthreptes simplicius</em></td>
<td>Plain Sunbird</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>1 0.05</td>
</tr>
<tr>
<td>Alcedinidae</td>
<td><em>Lacedo pulchella</em></td>
<td>Banded Kingfisher</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
</tr>
<tr>
<td>Pycnonotidae</td>
<td><em>Pycnonostrum melanoleucos</em></td>
<td>Black-and-white Bulbul</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
</tr>
<tr>
<td>Ramphastidae</td>
<td><em>Calomerus fuliginosus</em></td>
<td>Brown Barbet</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>1 0.05</td>
</tr>
<tr>
<td>Muscicapidae</td>
<td><em>Enicurus ruficapillus</em></td>
<td>Chestnut-naped Forktail</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
</tr>
<tr>
<td>Timaliidae</td>
<td><em>Stachyris malacalata</em></td>
<td>Chestnut-rumped Babbler</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
</tr>
<tr>
<td>Trogonidae</td>
<td><em>Harpactes orthophaeus</em></td>
<td>Cinnamon-rumped Trogon</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
</tr>
<tr>
<td>Dicaeidae</td>
<td><em>Prionochilus percussus</em></td>
<td>Crimson-breasted Flowerpecker</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>1 0.03</td>
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<tr>
<td>Muscicapidae</td>
<td><em>Muscipilla hodosgs</em></td>
<td>Pygmy Blue Flycatcher</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
</tr>
<tr>
<td>Strigidae</td>
<td><em>Oto rufescens</em></td>
<td>Reddish Scope Owl</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
</tr>
<tr>
<td>Timaliidae</td>
<td><em>Malacopteron affine</em></td>
<td>Sooty-capped Babbler</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
</tr>
<tr>
<td>Nectariniida</td>
<td><em>Arachnothera magna</em></td>
<td>Streaked Spiderhunter</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>1 0.05</td>
</tr>
<tr>
<td>Muscicapidae</td>
<td><em>Emias thalassinus</em></td>
<td>Verditer Flycatcher</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>1 0.05</td>
</tr>
<tr>
<td>Muscicapidae</td>
<td><em>Ficedula zanthopygia</em></td>
<td>Yellow-rumped Flycatcher</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>354  479</td>
<td>456</td>
<td>619</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Fisher’s alpha diversity index</th>
<th>Margalef’s richness index R_1</th>
<th>McIntosh evenness index E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two years post-harvested hill</td>
<td>15.43</td>
<td>8.18</td>
<td>0.855</td>
</tr>
<tr>
<td>Dipterocarp tropical rainforest</td>
<td>13.66</td>
<td>7.78</td>
<td>0.884</td>
</tr>
<tr>
<td>Ten years post-harvested hill</td>
<td>16.34</td>
<td>8.82</td>
<td>0.933</td>
</tr>
<tr>
<td>Dipterocarp tropical rainforest</td>
<td>16.02</td>
<td>9.02</td>
<td>0.929</td>
</tr>
</tbody>
</table>

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 (5.30±1.51).
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 affects 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 affects 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 changed 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 occurs over time which affects the avian richness and diversity through affecting food resources (Campbell 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 affects on avian distribution and diversity. However, these effects may vary from species to species. As the forest regenerates and recover the vegetation characteristics after logging may accommodate the higher bird species diversity and richness depending upon the rate of recovery process.

7. ACKNOWLEDGEMENT

The researchers would like to thank the Department of Wildlife and National Parks, Peninsular Malaysia (DWNP) for allowing us to conduct this research at different aged post-harvested hill dipterocarp rainforest habitats in Peninsular Malaysia. This research was funded by Research University Grants No: 03-01-111331RU.

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