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AVIAN DISTRIBUTION AND DIVERSITY IN FOREST GAP AND CLOSED CANOPY AREAS OF LOWLAND TROPICAL FOREST

Nik Fadzly Nik Rosely*, Shahrul Anuar Mohd Sah and Mashhor Mansor

[1]School of Biological Sciences,Universiti Sains Malaysia,11800 USM Pulau Pinang, Malaysia

Abstrak: Satu kajian ekologi berkaitan dengan kesan kawasan pokok tumbang dan kaitannya dengan taburan burung telah dijalankan di kawasan hutan di sekeliling Taman Botanikal Pulau Pinang yang termasuk di dalam Kawasan Hutan Simpan Bukit Kerajaan. Sejumlah 12 petak kajian telah dipilih, enam kawasan mewakili kawasan kanopi tertutup dan enam selebihnya mewakili kawasan hutan terbuka atau pokok tumbang. Persampelan burung telah dijalankan dengan kaedah pemerhatian dan persampelan dengan jaring kabut. Burung yang dikesan di kawasan hutan terbuka (229 individu) adalah lebih tinggi secara signifikan berbanding dengan kawasan kanopi tertutup (147 individu) ($\chi^2 = 17.88$, df = 1, $p < 0.01$). Taburan spesis burung yang dijumpai di kawasan hutan terbuka berbeza secara signifikan dari kawasan kanopi tertutup (Ujian-t = 2.487, df = 10, $p < 0.05$), di mana kawasan hutan terbuka direkodkan lebih banyak spesies berbanding kawasan kanopi tertutup. Perkiraan Diversiti (Indeks Shannon-Wiener dan Kesamarataan) dan Kekayaan Spesies (Margalef, Menhinick dan Kekayaan Sebenar), menunjukkan tidak terdapat sebarang perbezaan signifikan antara kawasan hutan terbuka dan kawasan kanopi tertutup. Kemungkinan bahawa saiz kawasan hutan terbuka adalah terlalu kecil untuk mempengaruhi nilai diversiti burung di kawasan ini.

Abstract: An ecological study concerning the effects of treefall gap areas and the association with bird distribution was conducted at the forest area around the Penang Botanical Garden which is encompassed within the Bukit Kerajaan Forest Reserve. A total of 12 study sites were chosen, six sites represent the closed canopy areas and the remaining six represent the gap areas. Bird sampling was conducted using point observation and mist netting methods. Birds detected in gap (229 individuals) areas were significantly higher compared to the closed canopy (147 individuals) areas ($\chi^2 = 17.88$, df = 1, $p < 0.01$). The distribution of species found in gap areas differs significantly from closed canopy areas (t-test = 2.487, df = 10, $p < 0.05$), where gap areas recorded more species than closed canopy areas. The diversity (Shannon-Wiener and Evenness) and species richness (Margalef, Menhinick and True Richness) calculation showed that there are no significant differences between gap areas and closed canopy areas. It is presumed that the size of the gap area is too small to affect the diversity of the birds.

Keywords: Treefall Gaps, Closed Canopy, Bird Diversity, Penang Island

*Corresponding author: nix_nik@yahoo.com

INTRODUCTION

Disturbance is both, a major source of temporal and spatial heterogeneity in the structure and dynamics of natural communities, and an agent of natural selection in the evolution of life histories (Sousa 1984). Disturbances have been viewed as uncommon, irregular events that cause abrupt structural changes in natural communities. Natural disturbances have contributed to the high biological diversity found in many tropical ecosystems (Restrepo & Gomez 1998). Such natural disturbances are thought to promote species diversity by preventing competitive exclusion and creating habitat heterogeneity, thereby allowing specialization and resource partitioning (Levey 1988; 1990). Much of the recent interest in tropical forest dynamics has centered on the relationship between naturally occurring disturbances and species diversity (Lawton & Putz 1988). One of the main examples of natural disturbances that promote diversity is natural or man-made treefall forest gaps. Studies conducted by Levey (1988), Schemske and Brokaw (1981), Wilson *et al*. (1982), and Wunderle *et al*. (2005) had shown that there is a specific pattern of relationship between tree distribution and the diversity of understory birds at the gap area. According to previous studies, gaps offer a concentration of resources that may attract numerous individual birds from many different species.

Wells (1999) stated that there are approximately 380 species of birds that depend on the forest or forest fringe in Peninsular Malaysia, and these form over 60% of the recorded avifauna. Davison and Fook (1995) recorded a total of 639 bird species in the Peninsular Malaysia. In addition, Jeyarajasingam and Pearson (1999) presented a list of 648 species recorded from West Malaysia and Singapore. However, Jenkins (2004) reported that a total of 747 species recorded from the whole of Malaysia. Therefore, this shows that new species are constantly found in Malaysia, indicating the wealth of richness and diversity of birds in this country.

Wong (1986) described the trophic organization of understory birds in a Malaysian dipterocarp forest. Flowers and fruits were considered as rare food resources for birds and the difference in forest types did not affect the birds feeding guild. Johns (1988) conducted research about selective logging and its effect to the frugivores and foliovores and found that the insectivorous bird groups are the most resilient compared to the frugivores due to the fact that insects are more dispersed in forests compared to fruits and flowers. Lambert (1992) also studied the effects of logging towards the diversity of birds in the Sabah lowland dipterocarp forest. In fact, the theme of disturbance and the diversity of birds were carried out extensively throughout the years. Studies conducted by Johns (1995), Styring and Zakaria (2000a, 2000b) and Peh *et al.* (2005) consisted of the effects of logging areas and their effects towards the diversity of birds. A lot of ecological avian research in Malaysia is seemingly concentrated in the logging area. However, there is a lack of interest in the study focusing specifically in gap areas with the distribution of birds in Malaysia. It is arguable in theory, that logging creates a gap area; however, the level of disturbance is quite different when compared to the naturally created gap. Therefore, this paper aims to investigate and compare the distribution of birds between gap areas and closed canopy areas; and also to compare the diversity and richness between gap areas against closed canopy areas.

MATERIALS AND METHODS

We conducted the study at Bukit Kerajaan Forest Reserve (N 05°26.256’ E 100°17.445’), which is considered as one of the most important forest reserves in Penang, due to its function as water source to part of Penang Island. The forest is also part of the tourist attraction to the state, whereby most of the pristine hill and lowland forest with native species are still intact and in relatively good condition. The forest, however, is not considered as a virgin forest as logging activities were conducted at the Bukit Kerajaan about 50 years ago. The forest reserve also offers a suitable habitat for many kinds of bird species. The actual sampling site is accessed by following a man-made trail starting from the base of the Bukit Kerajaan (entrance is via Penang Botanical Garden). Altogether, there are 12 study sites established in the surrounding forest area of the Botanical Garden. Six stations were classified as gap areas and the remaining six are considered as closed canopy areas (Figure 1). All the study sites are situated in the surrounding forest area of the Botanical Garden with the elevation of less than 300 meters from sea level.

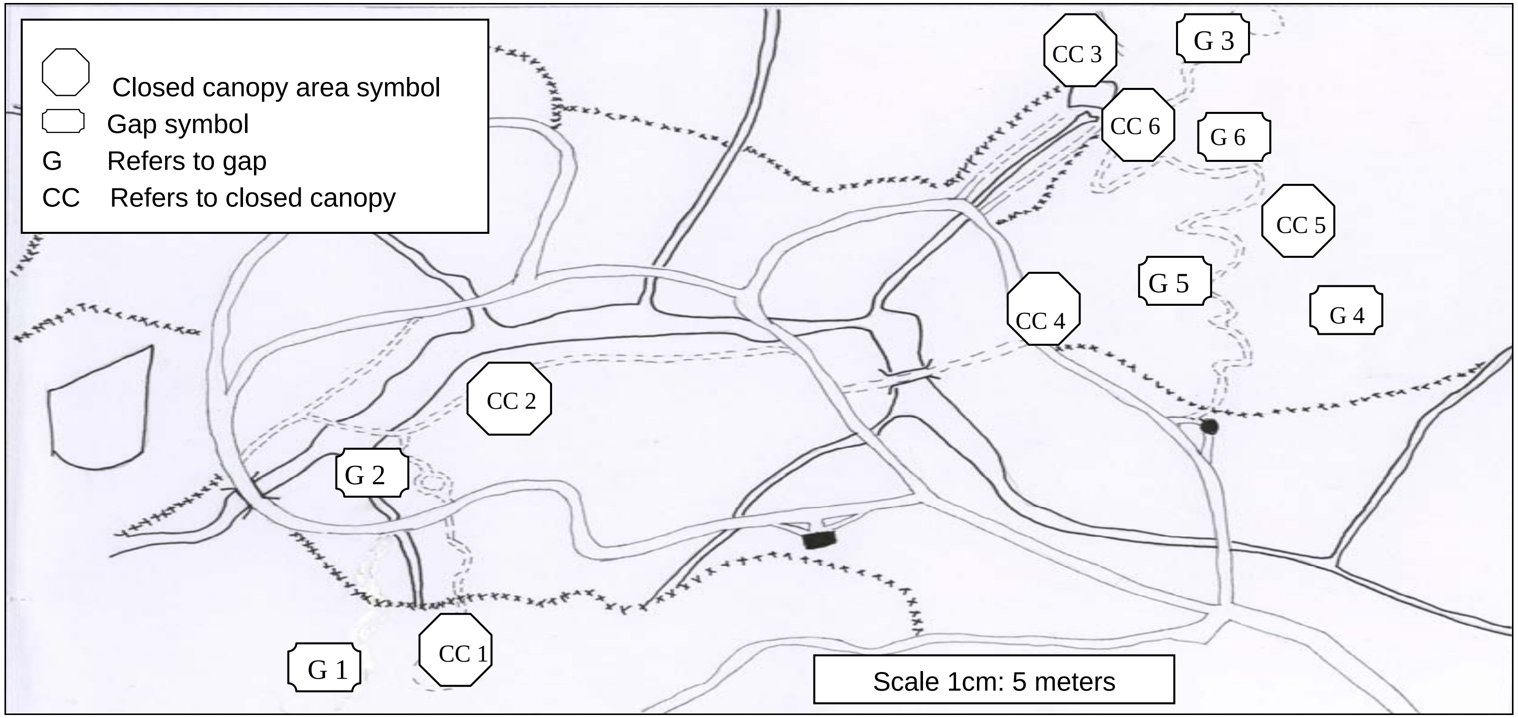

Figure 1: The location of the study areas at the Bukit Kerajaan area

In this study, the definition of a gap is based on the combination from Brokaw (1982) and Runkle (1992). Thus, gap area is defined as a vertical hole in the forest extending through all levels down to an average height of 2 m above the ground, the resulting hole in the canopy must be deep enough to expose to the sky the crowns of the stems that otherwise would be in the understory. Gaps are considered closed when replacement stems reach certain heights which are undistinguishable from the surrounding closed canopy forest or that the hole is closed due to the branching of the crowns from the neighboring closed canopy trees.

All the gaps in this study are caused by tree falls. The causes of these tree falls are varied, some are caused by wind throw, soil uprooting, and decaying tree trunks. The size of these gap areas varied from less than 100 m^2 [88.06 m^2 (gap 2), 75.84 m^2 (gap 6), 73.18 m^2 (gap 3)] and more than 100 m^2 [212.57 m^2 (gap 5), 146.74 m^2 (gap 4), 117.04 m^2 (gap 1)]. All the gap areas were estimated to be more than 5 to 10 years. The vegetation inside the gap area is varied. Some of the gaps are full of small seedlings, small trees, herbs and grasses while others are quite barren.

Mist-netting method was applied to obtain quantitative data for avian studies. The mist-nets are 9 x 4 m in size with mesh size is about 2.5 cm. The nets were opened during early morning (0800 hours) and closed before dusk (1830 hours). A single mist net was placed in an intact forest and also in gap area. An intact forest site is described as “a site with a dense upper canopy and little evidence of recent disturbances” (Levey 1988; 1990). The gap area and the closed canopy area are spaced 200 m from one another. Mist nets placed inside gap areas, are placed carefully to minimize visibility. The mist nets positions are changed periodically in order to reduce net avoidance by the birds. The birds that are captured through mist-netting are photographed, recorded and then set free. Identification was based on Jeyarajasingam and Pearson (1999).

Another type of method is by performing a fixed point observation/point counts. Fixed point observation requires a fixed point at an area. The observer remains still at the spot for about 5 to 10 minutes and observes the birds with a 10×25 binoculars However, the first 5 minutes are allocated for settling down period, in which the time that is needed for the birds in the surrounding area to settle down and ignore the presence of the observer. The observer would remain still in the center of the area. Birds that are sighted or heard in the area are recorded. Sampling was conducted starting from January 2004 to July 2005. Each study area was subjected to more than 200 hours of mist netting session and observation session throughout the study.

Analysis

Two types of methods were used to detect birds in this study, which were the fixed point observation and mist netting. Both of these methods were conducted simultaneously thus resulting in the combination values. The analyses performed throughout the study were based on the values taken from the combination of both methods.

1. Species Diversity
Measures of species diversity have application in conservation assessment. Krebs (1999) stated that diversity measures require an estimate of species importance in the community. Fowler *et al.* (1998) suggested that one of the most widely used indices is the Shannon-Wiener Index. According to Gibbs *et al.* (1998), the number of species (richness) and their evenness (equitability) are the components that define species diversity. 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. Therefore, both of the components will be treated into separate entity for further calculations.

2. Evenness
Evenness is closely tied with the species diversity and indicates equality of the poulations numerically. The evenness of a population is constrained between 0 and 1. The less variation in populations between the species, the higher the evenness value is acquired.

3. Species Richness
Species richness simply refers to the number of species in the community. Ludwig and Reynolds (1988) suggested two well known indices to be used as richness measures which are the Margalef and Menhinick index. Another type of richness calculation was performed using EstimateS (Colwell 2005). This calculation is based on the relative abundances of rare bird species in each habitat. Estimated 'true' species richness for each area can be generated using non-parametric species estimators (Colwell & Coddington 1994). Several species estimators were used since different estimators are best suited for different data sets (Soh *et al.* 2005; Chiarucci *et al.* 2003). The non-parametric estimators used are ACE, ICE, Chao1, Chao2, Jack1, Jack2, Bootstrap, MMRuns and MMMean. True Richness value is derived from the mean value of all the estimators used. For a detailed explanation of these estimators please refer to Colwell (2005).

RESULTS

A total of 376 individuals comprising of 43 species from 16 different families were either caught or sighted using observation and identified through sound recordings. There were two most frequently detected species, which are the *Dicrurus paradiseus* (Greater Racquet Tailed Drongo, 70 individuals) and the *Arachnothera longirostra* (Little Spiderhunter, 70 individuals). Appendix 1 lists out the species found in this study. There is a significant difference between the total number of individuals detected per-area (distribution of species), between closed canopy areas and gap areas ($t = 2.89$, $df = 10$, $p < 0.05$).

Two hundred and twenty nine (60.9%) individuals from the total individuals detected were found in gap areas, whereas closed canopy areas recorded a total of 147 (39.1%). Individuals detected in gap areas were significantly higher compared to the closed canopy areas (χ^2 = 17.88, df = 1, p < 0.01). In comparison of the total species found, 38 of the species was found in gap areas, compared to the 27 species found in closed canopy areas, although statistically it is not significantly different (χ^2 = 1.86, df = 1, p > 0.01). The gap areas also recorded birds from 15 different families, compared to only 11 of bird families found in closed canopy areas, however the difference is not statistically significant (χ^2 = 0.62, df = 1, p > 0.01).

A total of 38 species from 14 families, comprising of 316 individuals had been identified through point count observation. In an overall observed data, gap areas shows a significantly higher (χ^2 = 11.4, df = 1, p < 0.01) number of individuals (188) compared to the closed canopy areas (128).

There were 19 species from 11 families of birds that were caught in mist nets, altogether with a total of 60 individuals. Altogether, there was a significant difference (χ^2 = 8.06, df = 1, p < 0.01) in the total number of individuals caught in gap areas (41) compared to closed canopy areas (19).

Table 1 shows the Richness (Margalef and Menhinick), Diversity (Shannon-Weiner) and Evenness values for each area. There were no significant differences in any of the data sets for the comparison between gap areas and closed canopy areas (Margalef, t-test = 1.481, df = 10, $p > 0.05$; Menhinick, t-test = 0.712, df = 10, $p > 0.05$; Shannon-Weiner, t-test = 1.126, df = 10, $p > 0.05$; Evenness, t-test = -1.257, df = 10, $p > 0.05$).

Table 2 shows the 'True Richness' calculation using EstimateS. However, the results showed no significant difference for the Richness value between gap areas and closed canopy areas (t-test = 1.760, df = 10, $p > 0.05$).

Table 1: Species Richness, Diversity and Evenness values for each area

Sample	Margalef Index (Richness Index)	Menhinick Index (Richness Index)	Shannon-Weiner Index (Diversity Index)	Evenness	Num spec.
Gap Area 1	4.45	2.97	2.527	0.911	16
Gap Area 2	3.9	2.65	2.373	0.899	14
Gap Area 3	2.69	1.72	1.888	0.787	11
Gap Area 4	3.05	1.97	2.119	0.853	12
Gap Area 5	4.12	2.6	2.397	0.864	16
Gap Area 6	3.73	2.14	2.423	0.874	16
Close canopy 1	3.11	2.36	2.168	0.942	10
Close canopy 2	2.47	1.94	1.987	0.956	8
Close canopy 3	3.53	2.37	2.303	0.898	13
Close canopy 4	3.56	2.41	2.366	0.923	13
Close Canopy 5	3.42	2.4	2.151	0.865	12
Close canopy 6	3	2.08	1.954	0.815	11

Table 2: The True Richness values derived from the mean value of several non-parametric estimators

Site	G1	G2	G3	G4	G5	G6	CC1	CC2	CC3	CC4	CC5	CC6
Individuals (computed)	29.00	28.00	41.00	37.00	38.00	56.00	18.00	17.00	30.00	29.00	25.00	28.00
Sobs (Mao Tau)	16.00	14.00	11.00	12.00	16.00	16.00	10.00	8.00	13.00	13.00	12.00	11.00
ACE Mean	36.70	25.93	18.19	14.22	34.85	19.98	14.44	9.07	20.80	17.38	24.93	20.88
ICE Mean	41.88	27.09	22.98	33.07	44.03	26.85	25.07	10.06	25.37	21.64	40.29	23.00
Chao 1 Mean	32.67	18.90	17.25	14.67	29.50	20.17	14.17	8.50	19.00	15.50	15.60	17.00
Chao 2 Mean	52.00	22.00	20.00	44.00	46.25	24.00	22.25	9.13	19.13	19.13	32.25	17.00
Jack 1 Mean	27.33	21.56	16.67	19.56	26.39	23.56	16.61	10.83	19.61	19.61	20.50	16.67
Jack 2 Mean	36.33	25.32	20.33	25.83	34.49	27.32	21.16	10.15	22.49	22.49	26.83	19.49
Bootstrap Mean	20.60	17.38	13.43	15.03	20.21	19.39	12.75	9.56	16.02	16.02	15.46	13.52
MMRuns Mean	70.91	28.55	21.55	62.43	46.82	39.85	22.92	14.05	92.86	25.00	35.50	34.04
MMMeans (1 run)	54.38	30.04	17.62	21.02	31.34	27.37	27.89	16.63	25.67	28.19	33.38	18.89
True Richness	41.42	24.09	18.67	27.76	34.88	25.39	19.70	10.89	28.99	20.55	27.19	20.05

Appendix 1: List of birds found

	Family	Scientific name	Species list	G 1	G 2	G 3	G 4	G 5	G 6	C 1	C 2	C 3	C 4	C 5	C 6	Total Individual species
1	Alcedinidae	*Ceyx erithacus*	Black-backed Kingfisher	0	0	0	0	1	0	0	0	0	0	0	0	1
2	Columbidae	*Macropygia unchall*	Barred Cuckoo Dove	0	1	0	0	0	0	0	0	0	0	0	0	1
	Columbidae	*Chalcophaps indica*	Emerald Dove/Green Winged Pigeon	0	0	0	0	1	0	0	0	0	2	0	0	3
	Columbidae	*Macropygia ruficeps*	Little Cuckoo Dove	0	0	0	0	0	1	0	0	0	0	0	0	1
3	Corvidae	*Corvus macrorhynchos*	Large Billed Crow	0	0	0	0	0	0	0	0	0	1	1	0	2
4	Cuculidae	*Eudynamys scolopacea*	Asian Koel	1	0	0	0	0	0	0	0	0	0	0	0	1
	Cuculidae	*Cuculus sparverioides*	Large Hawk Cuckoo	0	0	0	0	1	0	0	0	0	0	0	0	1
	Cuculidae	*Surniculus lugubris*	Drongo Cuckoo	0	0	0	0	0	1	0	0	0	0	0	0	1
	Cuculidae	*Centropus bengalensis*	Lesser Coucal	1	0	0	0	0	0	0	0	0	0	0	0	1
5	Dicruridae	*Dicrurus leucophaeus*	Ashy Drongo	0	1	0	0	3	0	1	1	3	2	2	1	14

Appendix 1: *(continued)*

	Family	*Scientific name*	Species list	G 1	G 2	G 3	G 4	G 5	G 6	C 1	C 2	C 3	C 4	C 5	C 6	Total Individual species
	Dicruridae	*Dicrurus paradiseus*	Greater Racquet Tailed Drongo	1	0	8	13	9	14	1	0	2	2	9	11	70
6	Irenidae	*Irena puella*	Asian Fairy-BlueBird	0	0	0	0	1	0	0	0	0	0	0	0	1
7	Megalaimidae	*Megalaima haemacephala*	Coppersmith Barbet	0	0	1	0	0	0	0	0	1	0	0	0	2
8	Meropidae	*Merops leschenaulti*	Chesnut Headed Bee Eater	1	0	0	0	0	0	0	0	0	0	0	0	1
9	Motacilliinae	*Dendronanthus indicus*	Forest Wagtail	0	0	0	0	3	1	0	0	0	0	1	0	5
	Motacilliinae	*Anthus novaeseelandiae richardi*	Richards pipit	0	0	0	0	1	0	0	0	0	0	0	0	1
10	Muscicapidae	*Muscicapa dauurica*	Asian Brown Flycatcher	0	1	0	0	0	0	0	0	0	0	1	0	2
	Muscicapidae	*Cyornis tickelliae*	Tickell's Blue Flycatcher	0	0	0	0	0	0	0	0	0	1	0	0	1
11	Nectariniidae	*Aethopyga siparaja*	Crimson Sunbird	3	1	1	0	0	2	0	2	1	0	1	0	11
	Nectariniidae	*Arachnothera longirostra*	Little Spiderhunter	2	8	16	4	8	8	2	1	8	6	2	5	70
	Nectariniidae	*Nectarinia jugularis*	Olive-backed Sunbird	0	2	1	0	2	0	0	0	0	2	0	2	9
	Nectariniidae	*Hypogramma hypogrammicum*	Purple Naped Sunbird	1	1	0	0	0	0	2	2	0	0	0	0	6

Appendix 1: *(continued)*

	Family	*Scientific name*	Species list	G 1	G 2	G 3	G 4	G 5	G 6	C 1	C 2	C 3	C 4	C 5	C 6	Total Individual species
	Nectariniidae	*Arachnothera flavigaster*	Spectacled Spiderhunter	2	0	0	0	1	2	1	2	3	0	0	1	12
12	Pycnonotidae	*Pycnonotus goiavier*	Yellow vented Bulbul	0	2	2	3	0	5	1	3	4	2	1	1	24
	Pycnonotidae	*Pycnonotus finlaysoni*	Striped Throated Bulbul	0	0	0	0	0	0	0	0	1	0	2	0	3
	Pycnonotidae	*Criniger ochraceus*	Ocharaceous Bulbul	0	0	2	0	0	3	0	0	0	0	0	0	5
	Pycnonotidae	*Pyconontus plumosus*	Olive Winged Bulbul	0	0	0	1	0	6	0	0	0	0	0	1	8
	Pycnonotidae	*Tricholestes crineger*	Hairy Backed Bulbul	0	0	0	1	2	0	2	0	0	1	0	1	7
13	Strigidae	*Ninox scutulata*	Brown Hawk Owl	3	1	0	0	1	0	0	0	0	0	0	0	5
14	Sylviidae	*Phylloscopus borealis*	Artic Warbler	0	1	0	0	0	0	0	0	0	0	1	0	2
	Sylviidae	*Orthotomus sutorius*	Common Tailor Bird	0	3	1	0	1	2	3	0	0	1	0	2	13
	Sylviidae	*Orthotomus atrogularis*	Dark Necked Tailorbird	1	0	0	0	0	0	0	0	0	0	0	0	1
	Sylviidae	*Orthotomus sepium*	Ashy Tailorbird	7	2	4	1	0	3	0	0	0	1	2	0	20
15	Timalidae	*Alcippe brunneicauda*	Brown Fulvetta	1	0	0	0	0	0	0	0	0	0	0	0	1

Appendix 1: *(continued)*

	Family	*Scientific name*	Species list	G 1	G 2	G 3	G 4	G 5	G 6	C 1	C 2	C 3	C 4	C 5	C 6	Total Individual species
	Timalidae	*Trichastoma sepiarium*	Horsfield Babbler	1	2	4	2	0	3	0	2	1	3	0	0	18
	Timalidae	*Macronous gularis*	Striped Tit Babbler	1	0	0	2	1	1	1	0	1	0	0	0	7
	Timalidae	*Stachyris nigriceps*	Grey Throated Babbler	0	0	0	2	2	0	0	0	0	0	0	0	4
	Timalidae	*Pellorneum capistratum*	Black Capped Babbler	0	0	1	0	0	0	0	0	0	0	0	1	2
	Timalidae	*Pellorneum tickeli*	Buff Breasted Babbler	0	0	0	0	0	0	0	0	2	0	0	0	2
	Timalidae	*Malacopteron magnum*	Rufous Crowned Babbler	0	0	0	0	0	0	0	0	2	0	0	2	4
	Timalidae	*Malacopteron affine*	Sooty Capped Babbler	0	0	0	3	0	3	0	0	0	0	0	0	6
16	Turdidae	*Copsychus saularis*	Magpie Robin	2	0	0	1	0	0	0	0	0	0	2	0	5
	Turdidae	*Copsychus malabaricus*	White Rumped Shama	1	2	0	4	0	1	4	4	1	5	0	0	22
			Total	29	28	41	37	38	56	18	17	30	29	25	28	376

DISCUSSION

The overall number of birds (376) and species (43) detected is quite similar to the findings of Lee *et al.* (2005), in which they observed a total of 462 individuals from 37 different species in the forest interior of Fraser's Hill. Kumar (2005) reported an observation of 92 species observed at the Penang Botanical Garden area. The species encountered in this study has been reviewed and compared with other studies such as Kumar (2005; 2003), Bransbury (1993) and Rosli (1996).

This study shows that there is a significantly high number of individuals found in gap areas compared to the closed canopy areas. This concurs with the findings of Schemske and Brokaw (1981), Blake and Hoppes (1986), Levey (1988), Fuller (2000), Dunn (2004) and Wunderle *et al.* (2005). Until now, this study shows that gap areas attracted more birds compared to closed canopy areas. When tested for the diversity (Shannon-Wiener and Evenness) and species richness (Margalef, Menhinick and True Richness), there is no significant difference between gap and closed canopy areas.

The concept of diversity and richness is quite different from the total number distribution, total number of individuals and species affinity probability. Diversity and richness takes into account the number of species and the number of individuals (Ludwig & Reynolds 1988), whereas most of the previous study often focuses only on the number of individuals. Secondly, by referring to the studies by Schemske and Brokaw (1981), Blake and Hoppes (1986), Levey (1988; 1990), Fuller (2000) and Dunn (2004), none of them involves the subject of diversity and richness in full account. Although Wunderle *et al.* (2005) mentioned the diversity difference between gap areas and closed canopy areas (gap areas shows higher diversity) through bootstrap and Camargo Evenness measures, there is still another aspect that differentiate it from this study. The answer lies in the methods employed. Different methods of data acquisition produce different results. Similar to Blake and Hoppes (1986) and Wunderle *et al*. (2005) refers solely on mist-netting data, whereas this study relies on point count/observation and mist-nets. Another possibility is that the gap size in this study is too small compared to the previous published studies which could not produce any differences in the diversity and richness. Compared to Schemske and Brokaw (1981), their studied gap area is more than 250 m^2 (all gap areas sizes in this study are less than 250 m^2). It is possible that even though the diversity and richness did not differ, the number of individuals were higher in gaps because the birds might be using these small gap areas as their entry and exit of flying paths.

Birds are highly mobile organisms. Their movement is three dimensional and is not subjected only to the ground area. Therefore, it is only logical that multiple species of birds could move in and out of gap areas, and the surrounding closed canopy forest. The birds significantly different in the frequently of visits to the gap areas, the number of individuals and exactly what they seek in gap areas?

Treefall gaps are disturbance effect towards the vertical and horizontal structure of the forest. This creates a distinct microhabitat that differs from the understory of the surrounding forest in vegetation structure, plant species composition, microclimatic conditions and resource abundance (Denslow 1980; Schemske & Brokaw 1981; Brokaw 1982; Blake & Hoppes 1986). Blake and Hoppes (1986) also mentioned that birds may select habitats based on slight differences in vegetation or microclimate and thus there is reason to believe that birds are capable of recognizing and selecting treefall gaps as a distinct microhabitat in which to forage. In a simple explanation, birds are attracted to gap areas due to the abundance of food resources (insects), and perhaps nesting material (woody debris, litters). Greenberg and Langham (2001) suggested that an abundance of arthropod foods, nesting material, micro sites for nesting, and vegetative structure are the primary factors that attract breeding birds to the forest gaps.

In fact, Smith and Dallman (1996) also suggested that gaps facilitate territorial establishment of breeding males by giving them greater visibility and song projection, as well as clear territorial boundaries. Birds that use lower levels of a forest may be attracted to gaps because of a greater abundances of resources or because resources may be more accessible or visible in gaps (because of higher light levels) than in forest understory (Schemske & Brokaw 1981; Wilson *et al*. 1982). In this case, it is also prudent to mention about the concept of "space" that gap areas offer. Birds gather information about their environment mainly through visions by scanning surroundings and obvious characteristics of the environments (e.g., tall grass and large trees) also affect the amount and quality of visual information that is accessible in a particular body posture, thus reduced inputs and open space (e.g., gap areas) would greatly attract birds (Fernandez-Juricic *et al.* 2004). Bultman and Uetz (1984) stated that leaf litter is often abundant in gaps, and consequently soil and litter invertebrates are likely to be abundant as well. Higher soil and near-ground temperatures in gaps, relative to forest understory, also may increase insect activity levels over which relatively present in forest understory, thus attracting more insectivorous birds to gap areas. The dead tree stumps also provides shelter for dead wood invertebrates, again attracting more birds towards gap areas (Fuller 2000).

Altogether, gap areas are also considered as edge effect. An edge effect is the effect of the juxtaposition of contrasting environments on an ecosystem. This term is commonly used in conjunction with the boundary between natural habitats, especially forests, and disturbed or developed land. Edge effects are especially pronounced in small habitat fragments where they may extend throughout the patch. When an edge is created to any natural ecosystem, and the area outside the boundary is a disturbed or unnatural system, the natural ecosystem is seriously affected for some distance within the edge. In the case of a forest where the adjacent land has been cut, creating an open land/forest boundary, sunlight and wind penetrate to a much greater extent, drying out the interior of the forest close to the edge and encouraging rampant growth of opportunistic species at the edge. Change of air temperature, vapor pressure deficit, soil moisture, light intensity and levels of photosynthetically active radiation (PAR) occur at the edges (Restrepo & Gomez 1998).

To summarize, the explanation by Schemske and Brokaw's (1981). Perhaps encompasses all that had been discussed; birds are attracted to gaps because of the steep micro environmental gradient from the middle of the gap into the bordering mature phase results in a heterogeneous "edge" habitat with diversity of foraging opportunities and greater density of foliage. However, this is subjected to the size of the gap area, a small gap area might only show an increase in the individual counts without affecting the richness and diversity whereas a bigger gap area might affect both number of individual, richness and diversity.

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