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EDGE EFFECTS ON FORAGING GUILDS OF UPPERSTORY BIRDS IN AN ISOLATED TROPICAL RAINFOREST OF MALAYSIA

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ABSTRACT

The forest edge is the boundary between the forest area and the surrounding landscape. In this study forest edge is surrounded landscape which encompass of housing societies, highway, sports complex and equestrian park. Edge may directly or indirectly affect bird species in forest habitats because of various microclimate conditions (i.e., sunlight, wind, temperature, relative humidity) and microhabitat factors (i.e., vegetation species composition, structure and food resources). However, little information is available on the effects of edge on tropical forest birds. This study was conducted in an isolated tropical rainforest from March 2010 to June 2011 using a distance sampling point count technique to examine edge effects on the foraging guilds of upperstory bird species. In total, 1,618 individuals representing 61 upperstory bird species were detected. The analysis of feeding guilds indicated that sallying insectivores (F_6 = 22.95, $P < 0.001$), arboreal foliage-gleaning frugivores (F_6 = 3.87, $P < 0.001$) and arboreal foliage-gleaning insectivore/frugivores (F_6 = 4.42, $P < 0.001$) showed a significant difference in habitat selection at different distances from the edge to the interior of the forest. This finding shows that changes in the micro-environment have a significant effect on the distribution and richness of upperstory birds. This study demonstrated that the large-sized upperstory bird species, such as barbets, broadbills and malkohas tend to forage at the forest interior and infrequently observed at the forest edge. The study also showed that the upperstory bird species were influenced by the forest edge due to factors related to microclimate. However, the response of upperstory bird species may vary from species to species and from the forest edge to the interior. The birds selected specific microhabitat and microclimate characteristics that offered optimal food, shelter and breeding sites.

Key words: upperstory birds, feeding guild, micro environmental variables, forest edge, forest interior.

INTRODUCTION

Malaysia is characterized by a wealth of diverse forest resources i.e.,1641.0 million ha (Peninsular Malaysia; 5.38 mh, Sabah; 3.83 mh and Sarawak; 7.20 mh) of dipterocarp tropical rainforest. These forests provide ideal habitats for diverse wildlife species and are hotspots of biodiversity in Southeast Asia. Despite their richness in faunal diversity, these forests are being destroyed and degraded at an alarming rate due to anthropogenic activities such as urbanization and conversion into agricultural fields, which cause fragmentation and isolation. Habitat loss and isolation have posed serious threats to wildlife species. Several species have become locally extinct, and many are threatened. Edge effects represent a major problem of isolated forests. Edge effects due to urbanization have adversely affected the distribution and richness of various wildlife species. The impacts related to forest edge are among the most serious threats to habitat and forest integrity from local to global scales (Zheng *et al*., 2000). The isolation of forested areas has been shown to affect the species composition, relative abundance, and distribution of wild flora and fauna by reducing the amount and proximity of patches of suitable habitat and increasing the amount of edge (Manning *et al*., 2003).

A foraging guild is a group of avian species whose feeding behavior allows them to explore and utilize the same food resources in similar ways (Somasundaram and Vijayan, 2008). Foraging guilds provide information on bird community structure and the productivity of a particular habitat (Zakaria *et al*., 2002; Blondel, 2003; López de Casenave *et al*., 2008; Varasteh *et al*., 2010).

Detailed information on the effects of forest edge on avian foraging guilds inhabiting areas from the edge to the interior is scarce. Only a few studies have been conducted on the impacts of edge effects on birds in tropical rain forests (Varasteh *et al*., 2010; Rosli and Zakaria, 2011; Rosli *et al*., 2012) or on the effects of forest habitat fragmentation on bird distribution and diversity (Yahner, 2000; Maina, 2002). Moreover, no detailed study has been conducted on the effects of forest edge on upperstory bird species inhabiting the areas from the forest edge to the interior. There is an urgent need to examine the effects of forest edge on upperstory bird species to determine which upperstory bird species are sensitive to edge effects. The main objective of this study was to examine the effects of forest edge on the foraging guilds of upperstory bird species at various distances from the edge to the interior. The information is useful for understanding the habitat requirements of avian species in support of future management and conservation.

MATERIALS AND METHODS

Study Area: The Ayer Hitam Forest Reserve is located within 3° 00.00' N to 3° 02.20' N and 101° 37.90' E to 101° 40.00' E, approximately 20 km southwest of Kuala Lumpur, Malaysia. It is a 1248-ha isolated tropical lowland rainforest surrounded by housing projects, highways, a world-class sports complex and a well-known equestrian park (Figure 1). The AHFR is classified as secondary forest because it was harvested in the 1930s. The forest reserve was originally approximately 3,500 ha in size; however, due to development activities, only 1,248 ha is left, and the area was leased to Universiti Putra Malaysia in 1996 for approximately 99 years for the purpose of teaching, research and extension. This forest reserve is owned by Universiti Putra Malaysia and managed by Faculty of Forestry. This study was carried out by academic and research staff of the faculty of forestry and focused on birds. No endangered or threatened bird species have been recorded inhabiting this forest reserve. The permission was obtained from Animal Conservation Unit, Department of Wildlife and National Parks, Peninsular Malaysia to conduct this study. After obtaining the permit, the experimental design and sampling procedure was reviewed and approved by the Wildlife Ecological Research Unit, Faculty of Forestry, Universiti Putra Malaysia".

Bird Surveys: Birds were surveyed using a distance sampling point count technique (Buckland *et al*., 2004) for 15 consecutive months from March 2010 to June 2011. Seven categories of distances from the edge were established as follows: (1) 1 m (12 points), (2) 200 m (12 points), (3) 400 m (12 points), (4) 600 m (12 points), (5) 800 m (12 points), (6) 1000 m (14 points) and (7) 1200 m (14 points). A total of 88 point count stations at 200 m intervals (Figure 2) were established from the edge to the interior of the forest. This distance was selected to avoid counting the same birds twice at more than one station. The birds were surveyed monthly by a single observer from 0700 to 1000 for 10 days, and each point station was surveyed for 10 min. Ten-minute counts enabled the researcher to record sufficient numbers of individuals with minimal effort and disturbance (Jiménez, 2000; Lee and Marsden, 2008; Zakaria *et al*., 2009). During each survey, all of the bird species and individuals that were seen or heard were recorded. The distance from birds to the observer was determined using visual estimation within a range of 25 m. The choice of this range was based on consideration of the alternative methods whose strengths best matched this study, as recommended by Gregory *et al.* (2006). The design of this study considered the following factors: (i) suitability for dense habitats, such as forest and shrubs; (ii) suitability for surveying cryptic, shy, and skulking species; (iii) suitability for higher-density and more species-rich populations; (iv) suitability in situations where access is restricted; and (v) areas best situated for bird-habitat studies. Birds that were flushed in the field and whose original positions were known were recorded and included in the analysis. However, flying birds were not recorded because their original positions were unknown. The sampling methodology was based on (Buckland *et al*., 2004; Aborn, 2007; Nadeau *et al.,* 2008).

Habitat and Microclimate Factors: The habitat and microclimate factors were simultaneously recorded at the same location where the birds were detected to examine the influence of these variables on bird abundance and distribution from the forest edge to the interior. The vegetation variables (i.e., trees, shrubs, and grasses) were determined by employing the quadrat method (10 m x 10 m) (Fernandez-Alaez *et al*., 2002). Trees were categorized into various height and dbh classes to assess the effects of habitat heterogeneity. In each sample plot, the vegetation cover (%), species richness, vegetation type (such as trees, shrubs, and grasses), vegetation height (in meters) and vegetation diameter (inches) were determined. In addition, microclimate data, i.e., temperature, relative humidity, and light intensity were recorded simultaneously using a psychrometer. Light intensity was recorded using a LUX meter. The methodology followed that described by Chettri *et al.* (2005), Isacch *et al.* (2005) and Champlin *et al.* (2009).

DATA ANALYSIS

Bird Density: The feeding guild densities of bird species were determined using DISTANCE (Version 6.1; 16). The key to DISTANCE sampling analyses is to fit a *detection function* to the observed distances and use this fitted function to estimate the proportion of objects missed during the survey. Bird species with fewer than five detections were not analyzed due to their low sample size, as recommended and described by Buckland (2001). Densities were reported as groups per ha ± 95% confidence interval (range).

Feeding Guilds: The feeding guilds of all the sampled bird species were categorized based on major food, foraging behavior and habitat selection. It was difficult to analyze the feeding guild of each bird species separately; thus, we categorized birds into five major feeding guilds that exploited the same foraging sites, same food resources and foraging techniques in a similar way. As demonstrated in previous studies, bird species may be grouped into functional guilds that reflect the exploitation of the same food resources and similar foraging techniques in a particular habitat (Thorngate *et al*., 2006).

Correlation between Upperstory Birds and Habitat and Microclimate Variables: The relationships of upperstory birds with habitat and microclimate variables were examined by employing multiple regressions to perform a redundancy analysis (RDA). The analyses were performed with canonical correspondence analysis (CCA) software (Version 4.5) developed by ter Braak and Šmilauer (2002).

Comparison of the Means of the Foraging Guilds at Various Distances: A one-way analysis of variance (ANOVA) and a Tukey's (HSD) test (Analytical Software, version 8.1) (McGraw-Hill, 2008) were used to investigate the significance of differences between the means of variables characterizing the foraging guilds of upperstory birds observed at various distances from the edge to the interior.

RESULTS

In total, 1,618 bird individuals representing 61 upperstory bird species were recorded. The results of the study showed that upperstory arboreal foliage gleaners (insectivore/frugivores) were most abundant at distances 6 (1000 m) and 7 (1200 m) and least abundant along the forest edge, i.e., 1 m. Likewise, sallying insectivores were concentrated at distance 4 (600 m) and were least abundant at distance 2 (400 m). Arboreal foliage gleaners (insectivores) were concentrated at distance 2 (200 m), with the fewest species at distance 5 (800 m). Similarly, bark-gleaning insectivores were most common at distance 2 (200 m) and least common at distance 4 (600 m). Arboreal foliage gleaners (frugivores) were most abundant along the forest edge (1 m) and were lowest at distance 5 (Table 1).

A one-way ANOVA and a Tukey's (HSD) test demonstrated that the abundances of three foraging guilds, namely, sallying insectivores ($F_6 = 22.95$, $P < 0.001$), arboreal foliage-gleaning frugivores ($F_6 = 3.87$, $P <0.001$) and arboreal foliage-gleaning insectivore/frugivores ($F_6 = 4.42$, $P < 0.001$), were significantly different at different distances from the forest edge (Table 2).

The RDA showed that the foraging guilds of the upperstory bird species had a positive association (33.10%) with the microenvironmental variables. This result highlighted that the foraging guilds of upperstorybird species are strongly affected by the habitat and microclimate variables from the edge to the interior. For example, the first RDA axis and the second RDA axis indicated that 62.3% and 59.9% of the species-environment correlations, respectively, could be explained by the relationships shown on the RDA ordination biplot diagram (Figure 3). Furthermore, the results indicated that all the canonical axes differed significantly (P < 0.05; Monte Carlo simulations with 499 permutations) (Table 3).

Edge Effect on Overall Foraging Guild of Upperstory Bird Species: The RDA biplot diagram showed that all members of the foraging guilds of upperstory birds were influenced by the number of trees based on a wide range of diameters, i.e., 10–20 cm dbh, 30–40 cm dbh, and > 60 cm dbh, as well as relative humidity. The upperstory bird species often selected various distances, i.e., 200 m, 400 m, 600 m, 800 m, 1000 m and 1200 m, depending upon the availability and richness of food resources.

Response Variables: AFGF (arboreal foliage-gleaning frugivore), AFGI/F (arboreal foliage-gleaning insectivore/frugivore), SI (sallying insectivore), BGI (bark-gleaning insectivore, AFGI (arboreal foliage-gleaning insectivore), AFGI/C (arboreal foliage-gleaning insectivore/carnivore).

Edge Effect on the Arboreal Foliage-gleaning Insectivore/Frugivore Foraging Guild: The RDA ordination biplot showed that the arboreal foliage-gleaning insectivore/frugivore foraging guild preferred humid areas dominated by trees with a diameter between 30 and 40 cm and > 60 cm dbh. This finding indicated that the members of this guild preferred the forest interior and avoided the forest edge (Figure 4).

Edge Effect on the Arboreal Foliage-gleaning Insectivore Foraging Guild: The RDA biplot showed that the arboreal foliage-gleaning insectivores selected young stands of trees with a diameter between 10 and 20 cm dbh. This finding suggested that the members of this guild inhabited areas close to the forest edge rather than the interior (Figure 5).

Edge Effect on the Bark-gleaning Insectivore Foraging Guild: The RDA biplot diagram indicated that the bark-gleaning insectivores were influenced by trees with diameters of 20–40 cm and >60 cm, as well as relative humidity. The members of this guild preferred to utilize the forest interior, i.e., 200 m and 400 m, and they avoided the forest edge (Figure 6).

Edge Effect on the Sallying Insectivores and Arboreal Foliage-gleaning Frugivore Foraging Guild: The RDA biplot of the environmental variables showed that the sallying insectivores and arboreal foliage-gleaning frugivores were strongly influenced by trees with diameters ranging from 20 cm to more than 60 cm, as well as humidity. These foraging guilds comprised flycatchers, drongos and broadbills and were primarily detected in the forest interior at a distance of 400 m and 600 m (Figure 7).

Edge Effect on the Arboreal Foliage-gleaning Frugivore Foraging Guild: The RDA biplot showed that bird species representing the arboreal foliage-gleaning frugivores were influenced by the number of trees with diameters in a range of 30–40 cm dbh or greater than 60 cm dbh. This finding showed that the members of this guild preferred mature trees that bear a variety of fruits (Figure 8).

Edge Effect on theArboreal Foliage Insectivore/ Frugivore Foraging Guild: The RDA biplot showed that arboreal foliage insectivore/frugivores preferred the interior forest at various distances from the edge, i.e., 200 m, 400 m and 600 m. The members of this guild showed a positive association with young to mature trees with various diameters, i.e., 10–20 cm dbh, 30–40 cm dbh, and > 60 cm dbh as well as relative humidity. However, they avoided the forest edge (Figure 9).

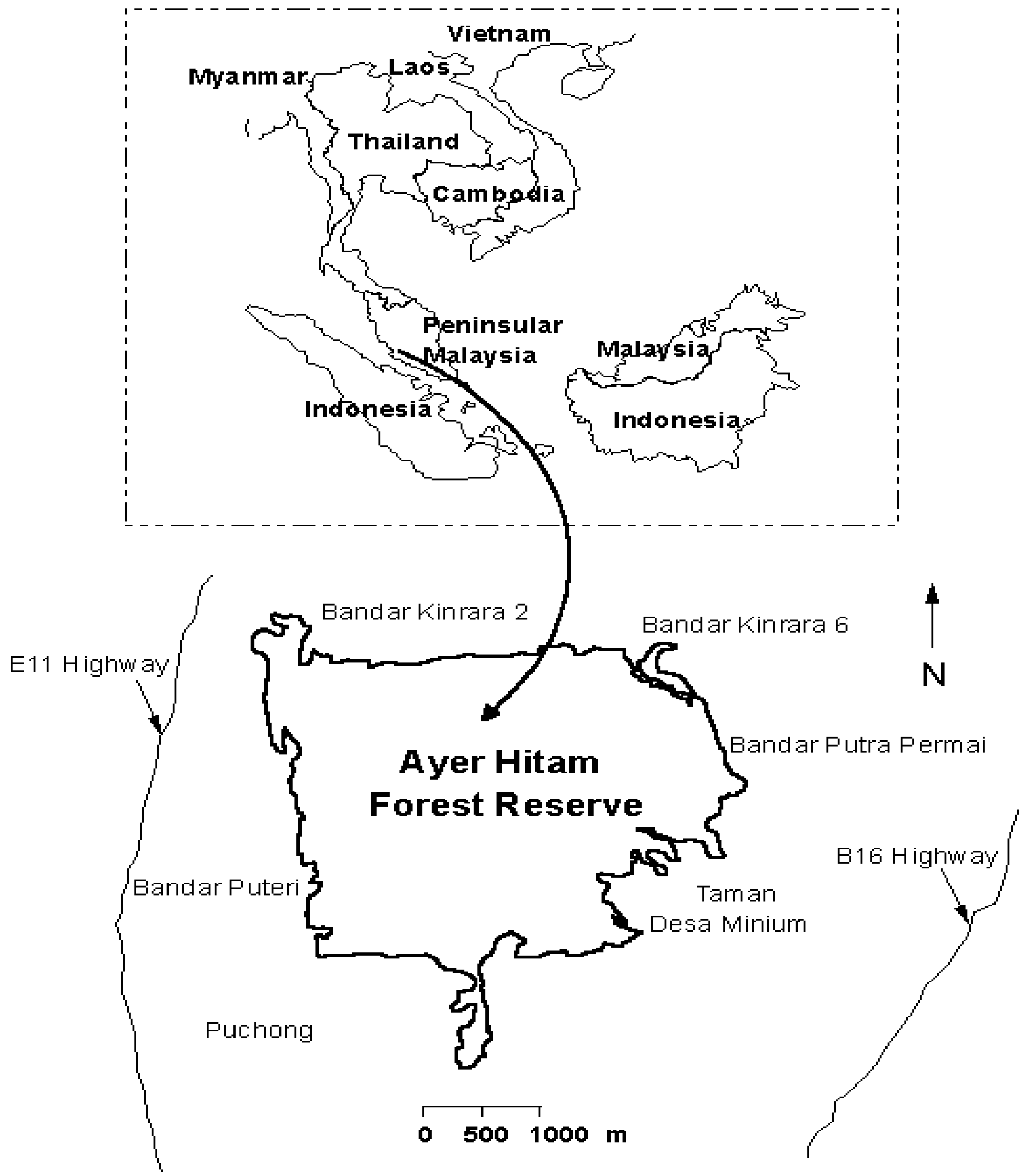

Figure 1. Location of Ayer Hitam Forest Reserve, Puchong, Selangor, Malaysia

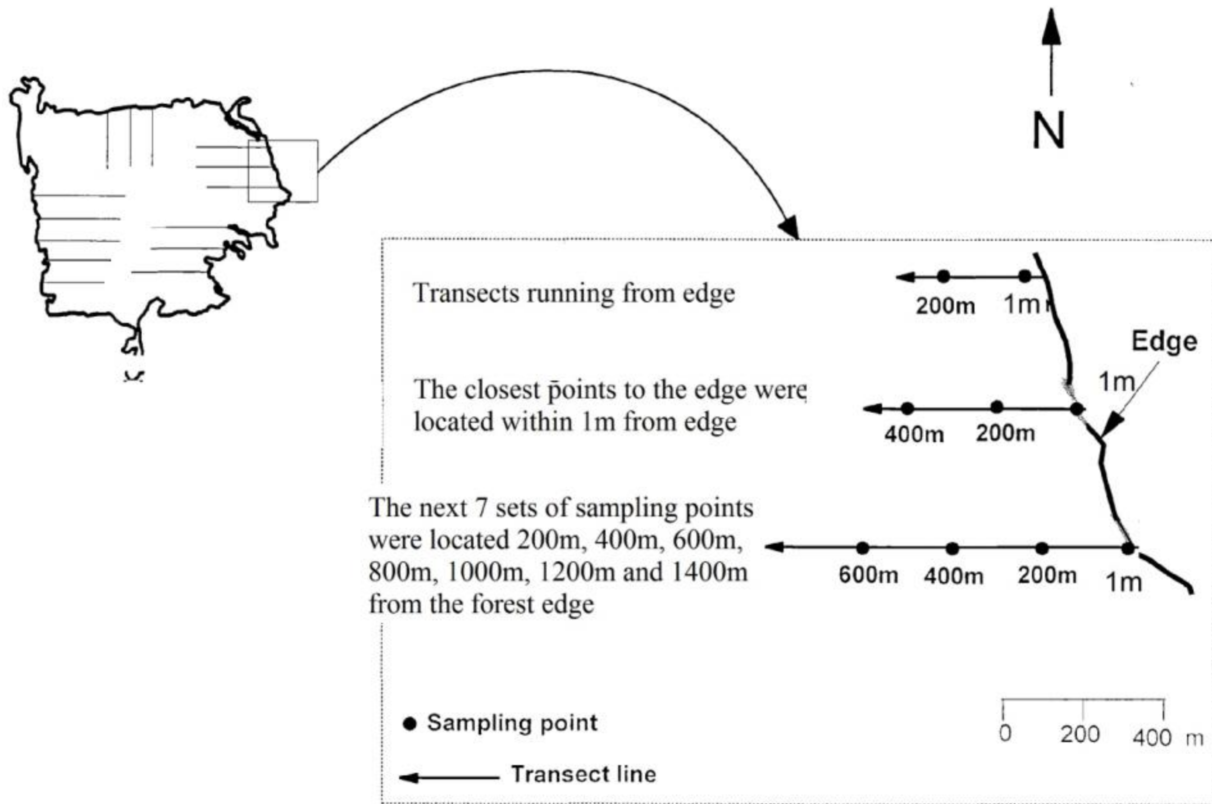

Figure 2. Distribution of point station from edge to anterior

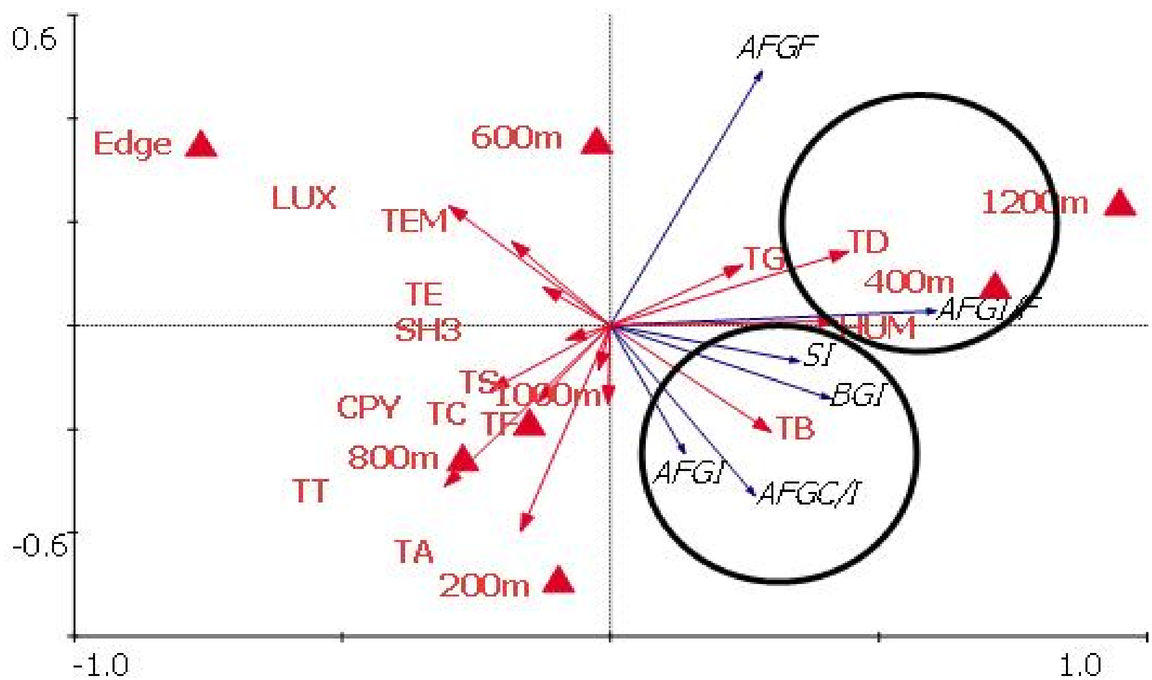

Figure 3.: RDA diagram of the distribution of foraging guilds of upperstory bird species at various distances from the forest edge to the interior relative to environmental variables in the isolated AHFR. The orientation of each variable relative to each distance is shown by an arrow whose length indicates the degree of influence of the edge effects on the foraging guilds; the triangle symbols represent the distance from the edge.

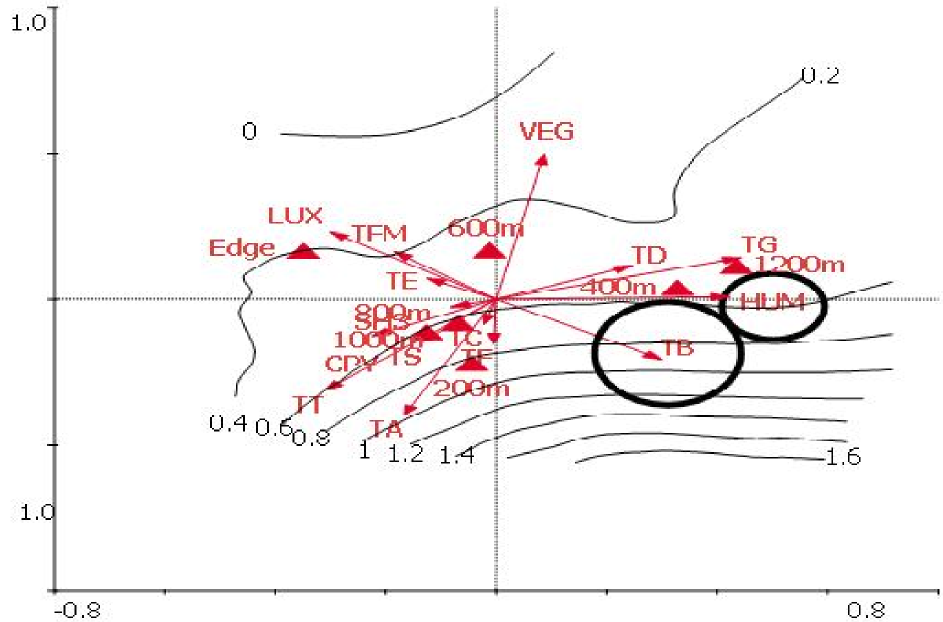

Figure 4. Biplot diagram of RDA of environmental factors that influence the arboreal foliage-gleaning insectivore/frugivore (AFGI/F) guild at various distances from the edge to the interior. The numbers correspond to the number of AFGI/F on the isolines. The orientation of each variable relative to each distance is shown by an arrow whose length indicates the degree of influence of edge effects on the foraging guilds; the triangle symbols represent the distance from the edge.

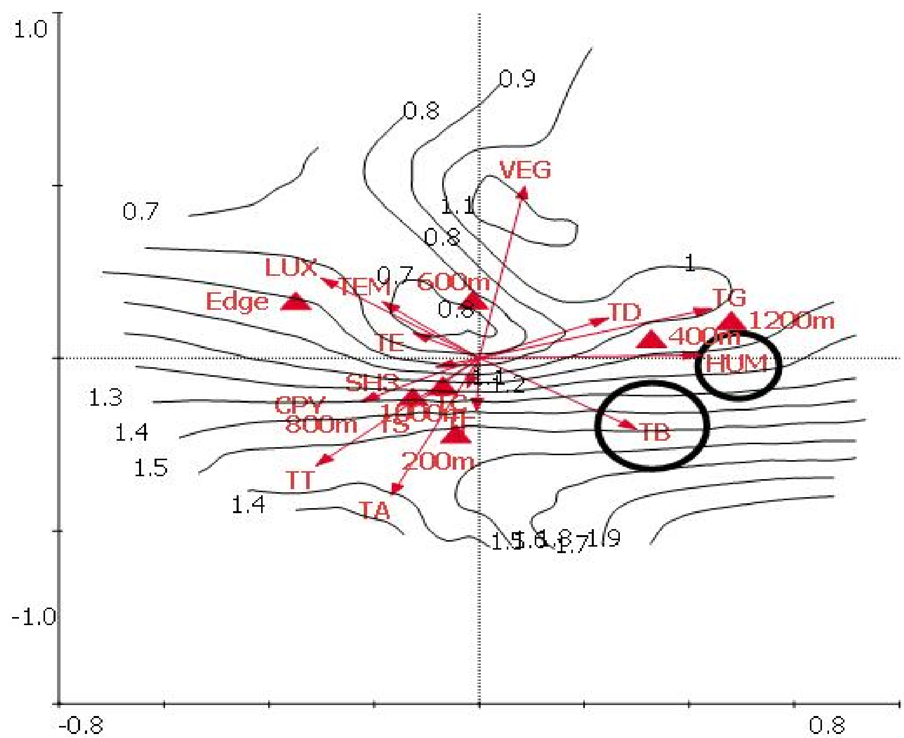

Figure 5. RDA biplot of environmental factors that influenced the arboreal foliage-gleaning insectivore (AFGI) guild at different distances from the edge to the forest interior. The numbers correspond to the number of AFGI on the isolines. The orientation of each variable relative to each distance is shown by an arrow whose length indicates the degree of influence of edge effects on the foraging guilds; the triangle symbols represent the distance from the edge.

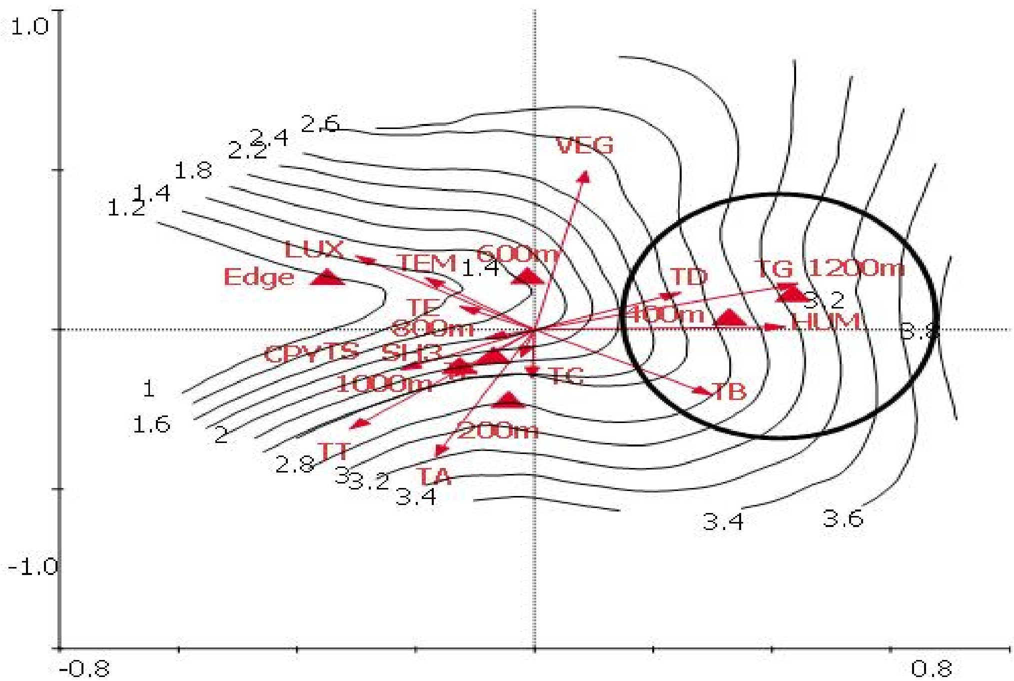

Figure 6. RDA biplot diagram of environmental factors that influenced the bark-gleaning insectivore (BGI) guild at different distances from the edge. The numbers correspond to the number of BGIs on the isolines. The orientation of each variable in relation to each distance is shown by an arrow whose length indicates the degree of influence of edge effects on the foraging guilds; the triangle symbols represent the distance from the edge.

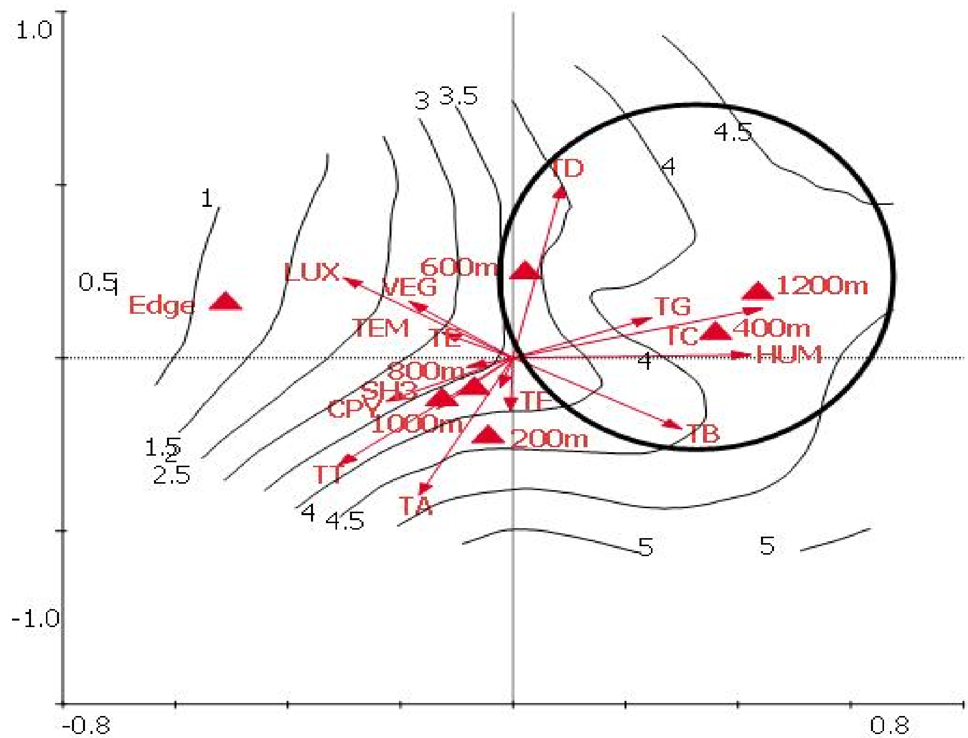

Figure 7. Main environmental factors that influenced the sallying insectivore (SI) guild at different distances from the edge. The numbers correspond to the number of SIs on the isolines. The orientation of each variable relative to each distance is shown by an arrow whose length indicates the degree of influence of edge effects on the foraging guilds; the triangle symbols represent the distance from the edge.

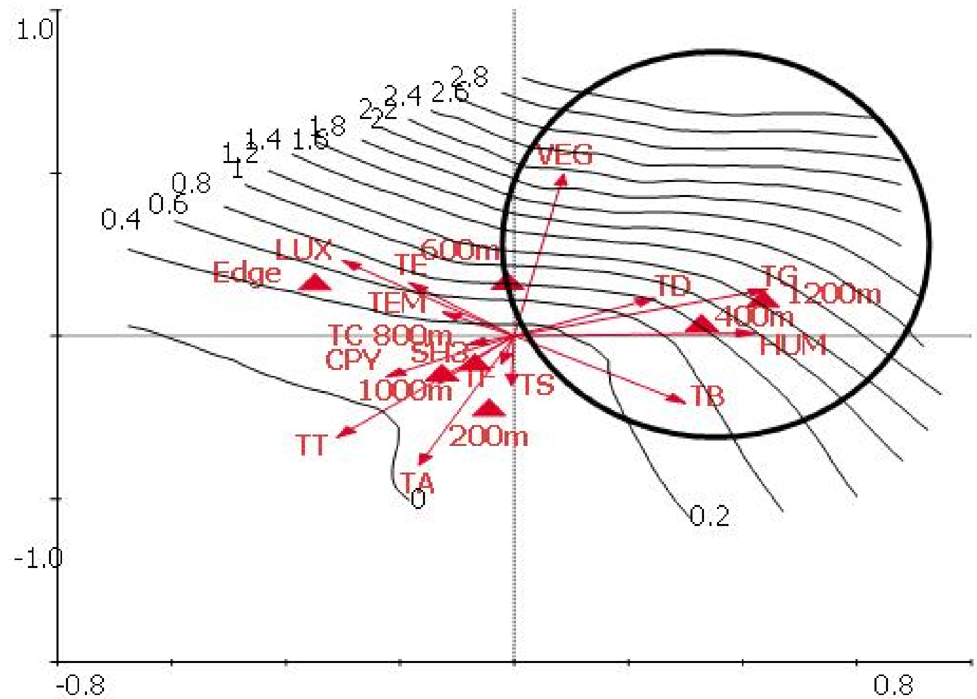

Figure 8. Principal environmental factors that influenced the arboreal foliage-gleaning frugivore (AFGF) guild at different distances from the edge. The numbers correspond to the number of AFGFs on the isolines. The orientation of each variable relative to each distance is shown by an arrow whose length indicates the degree of influence of edge effects on the foraging guilds; the triangle symbols represent the distance from the edge.

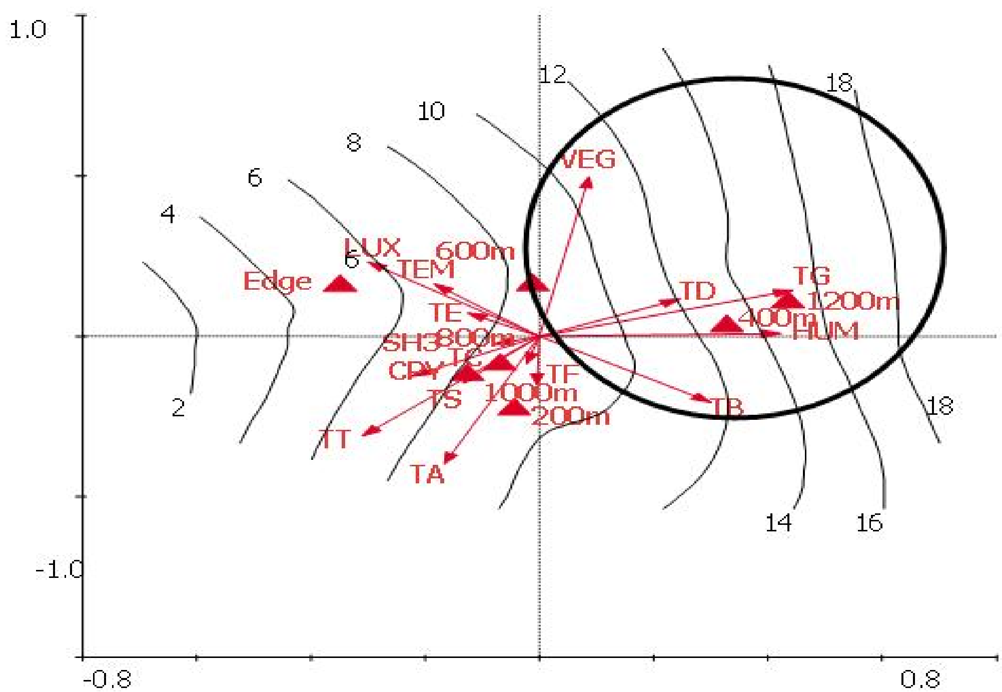

Figure 9. Main environmental factors that influenced the arboreal foliage-gleaning insectivore/frugivore (AFGF) guild at different distances from the edge. The numbers correspond to the number of AFGFs on the isolines. The orientation of each variable relative to each distance is shown by an arrow whose length indicates the degree of influence of edge effects on the foraging guilds; the triangle symbols represent the distance from the edge.

Table 1. Comparison of the feeding guilds of upperstory birds (%) at different distances from the forest edge based on the percentage of the number of individuals observed.

Foraging Guild		Distance from edge (m)						
		1(1)	2(200)	3(400)	4(600)	5(800)	6(1000)	7(1200)
Carnivore/Insectivore								
	[a]Afgc/i	3.24	5.02	4.38	2.65	5.56	5.68	1.4
Insectivore								
	[b]Afgi	8.65	12.13	7.62	4.17	3.53	3.98	4.3
	[c]Bgi	14.05	18.41	11.4	8.34	12.6	12.5	14.02
	[d]Si	22.16	17.57	22.2	29.54	26.3	18.2	19.16
Frugivore								
	[e]Afgf	9.74	3.76	6.73	7.57	1.52	2.84	6.07
Insectivore/Frugivore								
	[f]Afgi/f	42.16	42.26	47.70	47.73	49	56.8	55.14
Insectivore/Carnivore/Frugivore		0	0.85	0	0	1.52	0	0
Total Observations		185	239	342	264	198	176	214

[a]Arboreal foliage-gleaning carnivore/insectivore; [b]Arboreal foliage-gleaning insectivore; [c]Bark-gleaning insectivore [d]Sallying insectivore; [e]Arboreal foliage-gleaning frugivore; [f]Arboreal foliage-gleaning insectivore/frugivore

Table 2. Comparison of the means of individuals observed (± SE) for the feeding guilds of upperstory birds at different distances from the forest edge.

Foraging Guilds	Distance from Edge to Anterior							F	P
	Edge	200 m	400 m	600 m	800 m	1000 m	1200 m		
Carnivore/Insectivore									
Arboreal Foliage-gleaning	4.67 ± 1.67	3.00 ± 2.00	3.75 ± 2.75	2.33 ± 1.33	5.50 ± 1.50	3.33 ± 2.33	3.67 ± 2.18	0.19	0.976[ns]
Insectivore									
Arboreal Foliage-gleaning	4.00 ± 1.58	7.25 ± 2.72	6.50 ± 5.17	3.67 ± 1.76	7.00 ± 0	2.33 ± 1.33	4.50 ± 1.50	1.20	0.244[ns]
Bark-gleaning	4.33 ± 1.63	6.28 ± 2.27	6.50 ± 3.75	4.40 ± 2.23	4.17 ± 1.76	4.40 ± 1.75	6.00 ± 2.41	1.50	0.141[ns]
Sallying	6.83[a] ± 3.00	5.25[b] ± 3.42	7.60[a] ± 3.08	7.09[a] ± 2.88	5.78[ab] ± 3.26	4.57[b] ± 2.93	4.10[b] ± 1.57	22.95	0.000**
Frugivore									
Arboreal Foliage-gleaning	2.57[ab] ±1.34	1.28[ab] ± 1.28	3.28[a] ± 1.39	2.86[a] ± 1.61	0.43[b] ± 0.43	0.71[b] ± 0.36	1.86[ab] ± 0.98	3.87	0.000**
Insectivore/Frugivore									
Arboreal Foliage-gleaning Insectivore/Frugivore	7.09[b] ± 2.37	9.18[ab] ± 2.71	12.54[b] ± 4.83	9.00[ab] ± 2.79	7.50[b] ± 1.72	9.00[ab] ± 2.85	9.08[ab] ± 2.69	4.42	0.000**
Insectivore/Carnivore/Frugivore		0.66 ± 0.33			0.66 ± 0.33			9.00	0.174[ns]

Means of feeding guild were tested using Tukey's test of pairwise comparisons. '-' Indicates no data were recorded for this species at the survey point. '*' Indicates significant at 0.05, '**' Indicates significant at 0.001; 'ns' indicates not significant. Different means with different letters are significantly different.

Table 3. Summary table of RDA ordination of the feeding guilds of upperstory birds and their relationship with the environmental variables in the isolated AHFR.

Term	Axis				Total
	1	2	3	4	
Eigenvalues	0.158	0.065	0	0.029	1.000
Species–environment correlations	0.623	0.599	0.638	0.455	
Cumulative percentage variance of species data	15.8	22.3	27.3	30.1	
Cumulative percentage variance of species–environment relation	47.7	67.4	82.4	91.1	
Sum of all canonical eigenvalues					0.331
*Test of significance of all canonical axes					F–ratio = 1.55 P–value = 0.014

* Test of significance of the canonical axes was based on Monte Carlo permutations under the reduced model.

DISCUSSION

Habitat loss and fragmentation due to agriculture, forest logging, and urbanization may exert heavy pressure on natural forest resources. As a result, forest areas may become fragmented, isolated or degraded, and entirely lost. When habitat is being lost, not only particular area affected, but also remaining habitat becomes isolated and fragmented. Fragmented and isolated forest has adverse effects on avian density and distribution (Debinski and Holt, 2000) and it may also cause plants extinction (Arroyo-Rodrigez and Mandujano, 2006). Fragmentation and isolation of forest areas may increase the bird's demises through predation and brood parasitism (Hobson and Bayne, 2000; Hoover *et al*., 2006), reduced availability of food resources (Zanette *et al*., 2000; Lampila *et al.*, 2005) that reduced bird fecundity and sex ratio (Roberts, 2007) thus ultimately effects on avian reproduction success, population density, and distribution (Powell *et al*., 2000; Phillips *et al*., 2005; Niu, 2007).

In this study forest edge is surrounded landscape which encompass of housing societies, highway, sports complex and equestrian park. Edge is an important feature of forest ecosystems; it may alter the microclimate conditions that affect the interspecific interactions of avian species, such as food competition, predation and parasitism (Sisk and Battin, 2002). These effects ultimately influence the distribution, relative abundance, diversity, and richness of bird species inhabiting forest habitats. In addition, bird species may respond according to the distance from the edge to the interior forest.

The results of this study demonstrated an obvious pattern of interaction: the upperstory bird species were influenced by the microhabitat and microclimate characteristics. However, the response of upperstory bird species may vary from species to species and also from the forest edge to the interior, i.e., certain bird species utilized the canopy, others the middle story and others the lower story (Manning *et al.*, 2003; Harvey *et al*., 2008). Birds often select the forest habitats (Rosli and Zakaria, 2011; Rosli *et al*. 2012) that offer optimal food resources, shelter, and breeding sites at different distances from the forest edge. Foraging guilds are often used to determine the complexity of tropical forest ecosystems and the effects of forest edge as a border with the surrounding landscape. Avian foraging guilds also indicate the current status of forest health and productivity.

Furthermore, our results revealed that all the foraging guilds, i.e., bark-gleaning insectivores, sallying insectivores, arboreal foliage-gleaning frugivores and arboreal foliage-gleaning insectivore/frugivores, were associated with various-sized trees that provide different microclimate conditions. We observed that certain upperstory bird species, such as dollarbirds, minivets, and parakeets tended to be concentrated at the forest edge due to the proximity of different habitats (i.e., vegetation structure and floristic composition), whereas others (i.e., woodpeckers, barbets, broadbills, pigeons, and drongos) were concentrated in the interior. Upperstory birds often preferred large trees for foraging and nesting purposes (Zakaria *et al.*, 2002; Varasteh *et al.*, 2010). Certain bird species preferred open areas for foraging, whereas others selected dense vegetation due to their secretive behavior. This pattern might be due to high light intensity and temperature, which have significant effects on the forest vegetation structure and composition, as well as the richness and diversity of food resources. Likewise, it has been founded that large-sized canopy birds, such as barbets and broadbills, were affected by light intensity and temperature, i.e., they avoided disturbed forest, particularly the forest edge (Owens and Bennett, 2000; Sekecioglu *et al*., 2004; Robert and Raphael, 2007; Sodhi *et al*., 2008) and preferred to use undisturbed habitat, particularly the forest interior.

We also observed that the upperstory bird species, such as leafbirds, barbets, and bulbuls representing the arboreal foliage-gleaning insectivore/frugivore guild preferred to utilize the forest interior rather than the forest edge (Dale *et al*., 2000; Maina, 2002). This tendency could be due to the richness of fruits, insects, and other food resources. It may also be possible that the forest interior provides a variety of spatial configurations for many bird species, i.e., reduced bird visibility to predators, protection from harsh weather, and the availability of safe nesting and chick-rearing sites. Bird species are often associated with habitats that provide optimal conditions, a diversity of food and foraging sites, and safe breeding and roosting sites to perform various activities (Petit and Petit, 2003; Harvey *et al*., 2006; Robert and Raphael, 2007).

Conclusion: The results of this study revealed that the foraging of upperstory bird species is influenced by the microhabitat and microclimate characteristics from the forest edge to the interior. However, the response of upperstory bird species may vary at different distances from the forest edge to the interior. It was also suggested that upperstory bird species often select forest habitat from the edge to the interior that provides optimal resources such as food, shelter and breeding and foraging sites.

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Appendix I: Summary of findings on edge effects on upperstory birds.

No.	Species	Point Survey Station							Micro-Eenvironmental variable Effects											
		1	2	3	4	5	6	7	TA	TB	TC	TD	TE	TF	TG	TS	TT	LT	TP	HM
1	*Berenicornis comatus*	-	2	-	-	3	-	-	x						x		x	L/H	L/H	L/H
2	*Pericrocotus flammeus*	4	-	1	-	2	-	-							x		x	H	L	L/H
3	*Chloropsis cochinchinensis*	22	29	66	41	18	34	30		x	x	x	x	x		x	x	L	L	L/H
4	*Chloropsis sonnerati*	-	-	3	2	-	-	-				x	x			x		L	L	H
5	*Chloropsis cynapogon*	4	4	11	9	4	7	9				x	x			x		L	L	H
6	*Treron olax*	9	9	4	9	-	2	5		x		x	x			x		L/H	L/H	L/H
7	*Treron vernans*	5	-	3	2	-	2	2		x	x	x	x			x	x	L/H	L/H	L/H
8	*Ptilinopus jambu*	-	-	11	9	3	-	6						x			x	L	L	H
9	*Eurystomus orientalis*	11	4	-	-	-	-	-							x		x	H	H	L
10	*Cacomantis sonneratii*	-	-	1	1	-	-	-	x		x					x		L	L	H
11	*Surniculus lugubris*	1	3	-	-	-	-	-		x	x					x		L	L	H
12	*Cuculus micropterus*	5	4	1	-	-	1	-	x	x	x					x		L	L	H
13	*Cacomantis merulinus*	-	7	2	3	-	1	3	x	x	x					x		L	L	H
14	*Phaenicophaeus curvirostris*	3	9	12	5	7	8	2			x	x	x	x		x	x	L	L	H
15	*Phaenicophaeus sumatranus*	-	-	1	1	-	1	-		x	x	x				x	x	L	L	H
16	*Phaenicophaeus tristis*	3	1	1	-	-	-	1			x	x		x		x		L	L	H
17	*Phaenicophaeus chlorophaeus*	-	1	1	1	4	1	-	x	x	x					x		L	L	H
18	*Phaenicophaeus javanicus*	-	1	-	-	-	-	-			x					x		L	L	H
19	*Dicrurus aeneus*	-	1	-	1	-	-	2		x		x					x	L	L	H
20	*Dicrurus annectans*	2	-	2	-	2	1	1			x	x					x	L	L	H
21	*Dicrurus paradiseus*	20	29	34	30	31	22	17	x	x	x	x	x	x	x	x	x	L	L	H
22	*Eurylaimus javanicus*	2	13	22	20	19	15	25		x	x	x	x	x	x	x	x	L	L	H
23	*Eurylaimus ochromalus*	2	4	7	4	5	2	6			x	x				x		L	L	H
24	*Corydon sumatranus*	1	-	2	1	3	-	1				x	x	x	x		x	L/H	L/H	L/H
25	*Calyptomena viridis*	-	-	1	-	-	-	-						x			x	L	L	H
26	*Megalaima australis*	2	5	5	6	4	5	1		x	x	x	x			x		L	L	H
27	*Calorhamphus fuliginosus*	-	1	-	-	2	1	-					x	x	x		x	L	L	H
28	*Megalaima chrysopogon*	7	8	8	7	7	7	9				x	x	x	x	x	x	L/H	L/H	L/H
39	*Megalaima mystacophanos*	-	-	1	-	-	-	1							x		x	L/H	L/H	L/H
30	*Megalaima henricii*	-	-	1	2	1	-	-						x	x		x	L	L	H
31	*Merops viridis*	4	3	9	2	9	2	4			x		x	x			x	L/H	L/H	L/H
32	*Muscicapa dauurica*	3	1	1	-	-	-	5				x	x	x	x		x	L	L	H
33	*Rhinomyias umbratilis*	-	2	9	20	2	1	7						x	x		x	L	L	H
34	*Rhinomyias brunneata*	-	-	6	11	-	4	2						x	x		x	L	L	H
35	*Muscicapa sibirica*	-	-	-	4	2	-	-			x		x			x		L	L	H
36	*Ficedula elisae*	-	-	-	2	-	1	1		x	x					x		L	L	H
37	*Culicicapa ceylonensis*	-	-	2	3	1	-	1		x		x	x			x	x	L	L	H
38	*Terpsiphone paradisi*	-	1	4	2	1	-	-				x	x	x	x	x	x	L/H	L	H
39	*Philentoma pyrhopterum*	-	1	7	2	2	1	-				x	x	x		x	x	L/H	L	H
40	*Oriolus chinensis*	1	4	-	1	-	-	-		x	x	x					x	L/H	L/H	L/H

41	*Oriolus xanthonotus*	-	-	-	2	-	-	-				x					x	L/H	L/H	L/H
42	*Picus miniaceus*	12	18	25	13	12	11	13	x	x	x	x				x	x	L	L	H
43	*Meiglypte stukki*	5	4	5	4	5	2	1		x	x					x	x	L	L	H
44	*Meiglypte stristis*	2	-	-	-	-	-	-	x	x						x		L	L	H
45	*Picus mentalis*	3	2	4	-	1	2	5			x	x	x			x	x	L	L	H
46	*Dinopium javanense*	-	-	-	1	1	-	-				x					x	L	L	H
47	*Picus puniceus*	-	2	-	-	-	-	-				x					x	L	L	H
48	*Chrysocolaptes lucidus*	1	1	2	-	-	-	-					x	x			x	L	L	H
49	*Picus flavinucha*	3	8	1	-	1	2	1				x	x	x	x	x	x	L	L	H
50	*Blythipicus rubiginosus*	2	9	2	3	5	5	10	x	x	x	x	x			x	x	L	L	H
51	*Dinopium rafflesii*	-	-	-	1	-	-	-				x					x	L	L	H
52	*Psittacula longicauda*	4	-	-	-	-	-	-							x		x	L/H	L/H	L/H
53	*Loriculus galgulus*	-	-	3	-	-	1	-						x	x		x	L/H	L/H	L/H
54	*Psittinus cyanurus*	-	-	1	-	-	-	-							x		x	L/H	L/H	L/H
55	*Pycnonotus eutilotus*	-	-	-	-	-	-	2		x							x	L/H	L/H	L/H
56	*Pycnonotus atriceps*	-	-	-	-	-	1	2				x					x	L/H	L/H	L/H
57	*Criniger finschii*	7	7	17	10	11	14	6			x	x	x	x	x		x	L	L	H
58	*Hypsipetes criniger*	-	-	-	6	2	-	1					x	x				L	L	H
59	*Pycnonotus erythropthalmos*	4	3	5	5	4	8	6			x	x	x				x	L/H	L/H	L/H
60	*Gracula religiosa*	23	23	16	11	18	6	20					x	x	x		x	L/H	L/H	L/H
61	*Copsychus malabaricus*	8	15	22	7	7	5	6	x	x	x	x	x			x	x	L	L	H
	No. of species	(32)	(36)	(43)	(39)	(33)	(32)	(35)												
	No. of individuals	185	239	342	265	198	176	214												

'x' indicates where almost 80% of the birds were observed during the survey period. '-'Indicates no data were recorded for this species in the point survey. 1= At forest edge, 2 = 200 m from forest edge, 3 = 400 m from forest edge, 4 = 600 m from forest edge, 5 = 800 m from forest edge, 6 = 1000 m from forest edge and 7 = 1200 m from forest edge. TA (number of trees < 10 cm dbh), TB (number of trees 10-20 cm dbh), TC (number of trees 20-30 cm dbh), TD (number of trees 30-40 cm dbh), TE (number of trees 40-50 cm dbh), TF (number of trees 50-60 cm dbh), TG (number of trees > 60 cm dbh), TS (number of trees < 10 m tall), TT (number of trees > 10 m tall), SH (% of shrubs), VG (% of ground vegetation), CP (% of canopy cover), LT (light intensity), TP (temperature), HM (humidity); L=low, H=high.