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The Influence of Habitat Structure on Bird Species Composition in Lowland Malaysian Rain Forests

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Abstrak: Kajian burung telah dijalankan di kawasan batu kapur Bukit Kepala Gajah di Lenggong, Perak, dari Julai 2010 hingga Januari 2011. Kawasan kajian telah dibahagikan kepada tiga zon: pinggir hutan, perantaraan hutan dan pedalaman hutan. Kaedah persampelan jarak *point count* telah digunakan dalam kajian ini. Sejumlah 7789 pemerhatian telah direkodkan, mewakili 100 spesies-spesies burung daripada 28 famili. Pycnonotidae, Timaliidae dan Nectariniidae adalah famili dominan dan menunjukkan bilangan pemerhatian yang tertinggi dalam kawasan kajian, manakala Motacillidae menunjukkan bilangan pemerhatian yang paling sedikit. Spesies-spesies burung telah dikelaskan kepada tiga kumpulan pemakanan: pemakan serangga, pemakan buah dan lain-lain (pemakan segala, pemakan daging, pemakan madu dan pemakan bijirin). Kekayaan spesies burung-burung pemakan serangga adalah berbeza secara signifikan antara zon-zon hutan yang dikaji (Kruskal-Wallis: α=0.05, H=10.979, d.f.=2, p=0.004), dengan burung-burung pemakan serangga lebih banyak dijumpai di pedalaman hutan. Tiada perbezaan yang signifikan dijumpai antara kekayaan spesies di zon-zon hutan sama ada kumpulan pemakan buah atau gabungan kumpulan pemakanan yang lain-lain.

Kata kunci: Kumpulan Pemakanan, Pinggir Hutan, Burung-burung Pemakan Serangga, Habitat Batu Kapur, Malaysia, Hutan Tropika

Abstract: Bird surveys were conducted in the Bukit Kepala Gajah limestone area in Lenggong, Perak from July 2010 to January 2011. The study area was divided into three zones: forest edge, forest intermediate and forest interior. A point-count distance sampling method was used in the bird surveys. The study recorded 7789 detections, representing 100 bird species belonging to 28 families. Pycnonotidae, Timaliidae and Nectariniidae were the dominant families overall and showed the highest number of observations recorded in the study area whereas Motacillidae showed the fewest observations. The bird species were grouped into three feeding guilds: insectivores, frugivores and others (omnivores, carnivores, nectarivores and granivores). The species richness of insectivorous birds differed significantly among the forest zones sampled (Kruskal-Wallis: α=0.05, H=10.979, d.f.=2, p=0.004), with more insectivorous birds occurring in the forest interior. No significant differences were found among the zones in the species richness of either the frugivore guild or the composite others guild.

Keywords: Feeding Guilds, Forest Edge, Insectivorous Birds, Limestone Habitat, Malaysia, Tropical Forest

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INTRODUCTION

Tropical forest ecosystems are deteriorating rapidly as a result of human impacts. Therefore, it is important to identify the bird species that are most influenced by the impacts and the extent to which habitat disturbance has affected biodiversity (Willis 1984). This type of study has been intensively pursued, and the identification of those species that are most sensitive to the rapid loss of tropical forests has received considerable attention (Canaday 1997).

Forest biodiversity is greatly affected by human activities, such as mining operations, agricultural expansion (Canaday 1997), timber extraction (Thiollay 1992) and the hunting of wild animals (Redford 1992). In Peninsular Malaysia, most of the pristine lowland dipterocarp forests have been exploited or harvested for timber and commercial crops (Caufield 1991). All of these activities have surely reduced the diversity of the fauna to an extent that reflects the degree of habitat disturbance.

Birds are effective as bio-indicators in the study of the impacts of forest disturbance and habitat structure on species composition (Karr *et al.* 1990). Tropical birds are highly diverse, and their ecological niches are extremely varied and reasonably well known. Birds are also more easily detected than other types of animals because of their often loud vocalisations and distinctive colours.

Quarries have been considered the primary threat to the survival of karst-associated species. They are creating undeniable problems for biodiversity conservation in Southeast Asia (Kiew 1991; Vermeulen & Whitten 1999; Sodhi & Brook 2006). Little information is available to help identify the feeding guilds of bird species that are most sensitive to habitat disturbance, and relatively few studies have been conducted on the fauna of limestone areas, particularly birds. The objectives of this study are to examine the influences of habitat structure and disturbance, specifically the edge effects in forests near limestone areas, on bird species composition and to identify the feeding guilds that are most sensitive to habitat disturbance.

MATERIALS AND METHODS

Study Site

Field work was conducted at the Bukit Kepala Gajah limestone area in Lenggong, Perak, located between 5°7.957'N 100°58.432'E and 5°7.728'N 100°58.410'E, from July 2010 to January 2011. Bukit Kepala Gajah, 1 of 8 limestone hills in the Lenggong Valley, is approximately 150 m above sea level and is located approximately 3 km north of Lenggong town. The Lenggong Valley is an important archaeological site. Evidence of Palaeolithic human settlement has been found in the valley (Majid 1994). The vegetation is generally mixed and includes limestone forest, lowland dipterocarp forest, orchards and secondary forest. Birds were surveyed at the sites in three zones: forest edge, forest intermediate and forest interior (Fig. 1). This survey was carried out on ordinary soils near the limestone area.

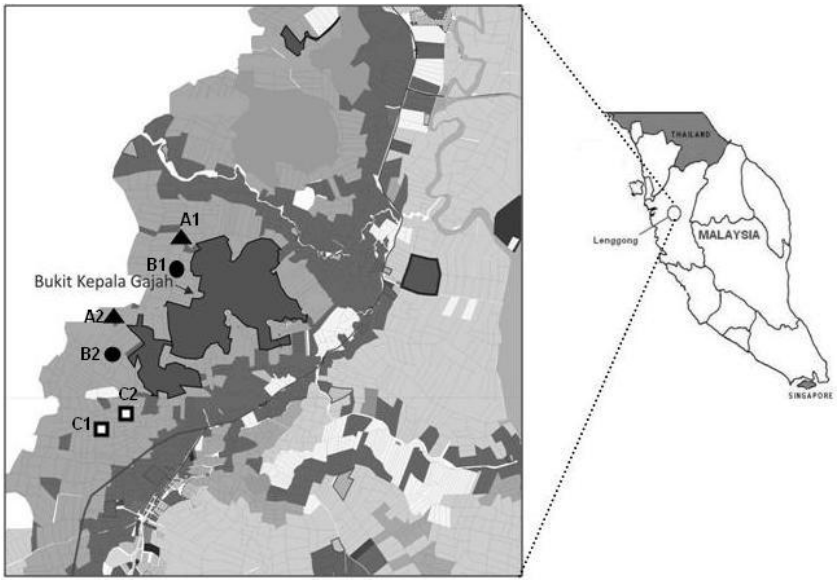

Figure 1: Schematic showing locations of study sites in Lenggong limestone area, Perak, Malaysia. Zones are indicated as follows: ▲ - forest edge, ● - forest intermediate, ◘ - forest interior. A, B and C refer to the two replicate sets of sites.

Point Counts

A point-count distance sampling method was used in the bird surveys. Six transects (two in each forest zone) were randomly placed at the study sites and surveyed 15 days per month. The transects were approximately 300 m long and spaced 150 m apart, with census stations positioned at 50 m intervals. Bird surveys were conducted from 0700 to 1100 and 1600 to 1830. The surveys were only performed during suitable weather (i.e., in the absence of rain or strong wind). At each plot, all birds seen and heard during a 10 min observation period were recorded. Flushed birds were recorded at their original position, but flying birds were not recorded because their original positions were unknown. The bird identification was aided by Robson (2008).

Data Analysis

Kruskal-Wallis tests were performed to compare the number of species found in the three habitat zones. Separate tests were performed for each of the three bird feeding guilds designated for this study (i.e., insectivores, frugivores and others). A two-by-two G-test of independence was used to identify the bird feeding guilds that were more likely to be restricted to the undisturbed area. [Note: species were counted based on species found in forest interior according to their presence or absence in forest edge, and vice versa]. Birds flying silently high in the air (e.g., swallows, raptors, swifts) were not included in any of the analyses.

RESULTS

Bird Species

The study recorded a total of 7789 bird detections, that belonged too 100 bird species (Appendix 1). Transect walks done were about 1260 (105 days × 6 transects × 2 times per day). A total of 2603 bird detections occurred in the forest edge habitat, 2826 in the forest intermediate and 2360 in the forest interior. In all, 58 species were recorded in the forest edge, 83 species in the forest intermediate and 71 species in the forest interior. A total of 11 species were found only on the forest edge (18.97%). A total of 5 species (7.04%) were found only in the forest interior and 1 species was found only in the forest intermediate (1.20%).

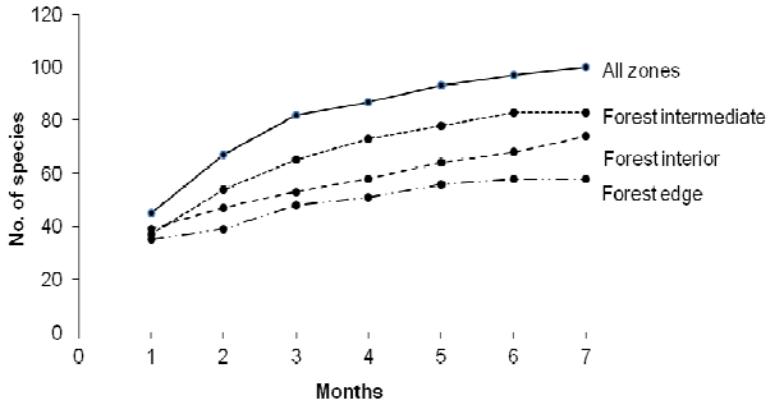

Figure 2: Species accumulation curves of bird species in Lenggong limestone area, Perak.

Lonchura striata (283 observations; 10.87%), *Lonchura punctulata* (213 observations; 8.18%) and *Amaurornis phoenicurus* (188 observations; 7.22%) were the three most abundant bird species recorded on the forest edge. *Merops leschenaulti* (278 observations; 9.84%) *Prinia flaviventris* (113 observations; 4.00%) and *Iole olivacea* (102 observations; 3.61%) were the three most abundant bird species recorded in the forest intermediate. *Stachyris erythroptera* (184 observations; 7.80%), *Macronus gularis* (89 observations; 3.77%) and *Arachnothera longirostra* (86 observations; 3.64%) were the three most abundant bird species recorded in the forest interior. As the sampling progressed each month, the survey yielded fewer new bird species in the forest interior. The graph of cumulative species numbers reached an asymptote in the forest edge and in the forest intermediate (Fig. 2).

Bird Families

In all, 28 bird families were recorded during the study period. Pycnonotidae (1063 observations; 13.65%), Timaliidae (976 observations; 12.53%) and Nectariniidae

(740 observations; 9.50%) were the three most dominant families and yielded the highest number of observations recorded in the study area whereas Motacillidae was the family recorded the least frequently in the study area (1 observation; 0.01%).

Estrildidae (496 observations; 19.05%), Pycnonotidae (446 observations; 17.13%) and Cisticolidae (336 observations; 12.91%) were the three most dominant families and represented the highest number of observations recorded in the forest-edge habitat. Pycnonotidae (387 observations; 13.69%), Meropidae (328 observations; 11.61%) and Nectariniidae (301 observations; 10.65%) were the three most dominant families and represented the highest number of observations recorded in the intermediate zone. Timaliidae (563 observations; 23.86%), Nectariniidae (292 observations; 12.37%) and Pycnonotidae (230 observations; 9.75%) were the three most dominant families and represented the highest number of observations recorded in the forest interior.

Feeding Guilds

The bird species were grouped into three feeding guilds: insectivores, frugivores and others (omnivores, carnivores, nectarivores and granivores). Insectivores were the most abundant group (52%), followed by frugivores (24%) and others (24%). For improved clarity, we determined the feeding guilds according to the predominant food type. For example, birds that fed predominantly on fruits and fed on insects and/or nectar as items of secondary importance were classified as frugivores. This approach is consistent with the classifications used by Canaday (1997), Fogden (1972) and Wells (1999, 2007).

The species richness of insectivorous bird species differed significantly between the zones sampled (Kruskal-Wallis: α=0.05, H=10.979, d.f.=2, p=0.004). Insectivorous birds (1436 observations) were observed more frequently in the forest interior (Fig. 3). No significant differences in species richness among the zones were found for frugivores (H=5.156, d.f.=2, p=0.076) or others (H=4.257, d.f.=2, p=0.119).

The decline in the number of insectivorous birds at the forest edge is supported by the data from this study and from seven other studies on tropical forests. The studies showed a significantly greater restriction of insectivores to the forest interior, compared with other feeding guilds (Table 1). The data from other studies were selected to represent a variety of habitats and were adapted from Canaday (1997).

DISCUSSION

The numbers of bird detections in the forest zones surveyed are equivalent to a range of 30 to 36 sightings per species in each zone. This result suggests that bird abundance did not differ greatly among the three zones. The intermediate zone had a high total species number but the fewest overlapping species between zones. This result suggests that the high species number in the intermediate zone was primarily a consequence of the overlap between the edge

and interior communities. The high species number did not represent a distinct community that depended on the conditions of the intermediate zone.

The results suggest that insectivorous birds are the feeding guild that is most influenced by habitat disturbance. Other studies have also shown that insectivorous birds are more sensitive to habitat disturbance than other feeding guilds (Table 1). Kruskal-Wallis tests indicated that only the insectivorous birds showed a significant difference in species richness among the zones. More insectivorous birds were observed in the forest interior. Insectivores are highly sensitive to habitat modification (Laurence *et al*. 2004) and they appear to be confined to areas with less disturbance (Tvardikova 2010). Generally, insectivores have high habitat specificity. They are more strongly restricted to the forest interior than other avian feeding guilds, especially in the tropical forest where habitat loss and its consequences are largely affected (Sekercioglu 2002). Insectivorous birds show a strong tendency to become more specialised and sensitive to prey abundance and behaviour because, unlike fruits, flowers and seeds, invertebrates actively avoid insectivores (Snow 1976).

The negative correlation between the species richness of insectivorous birds and the degree of impact from habitat loss may be due to the high degree of ecological specialisation among insectivores, food scarcity in the disturbed habitat, changes in microclimate and in predation rates, and interspecific competition.

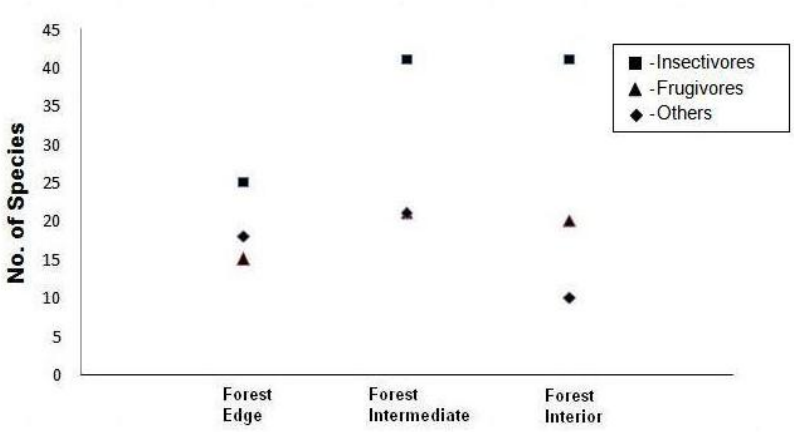

Figure 3: Numbers of insectivorous, frugivores and others bird species in three zones; forest edge, forest intermediate and forest interior.

Table 1: Numbers of bird species found in lowland tropical forest habitats. Diets: I-insectivores, O-other. Two-by-two G tests of independence (d.f.=1). Adapted from Canaday (1997).

	I	O	I/O	G	*p*
A. Present study					
Forest interior	27	14	1.9	4.778	0.029
Forest edge	11	17	0.6		
B. Cuyabeno Reserve, Ecuador (Canaday 1997)					
Forest interior	36	13	2.8	21.5	0.000004
Forest edge	17	44	0.4		
C. Miriti, Colombia (Andrade & Rubio-Torgler 1994)					
Undisturbed forest	20	2	10.0	4.1	0.044
Young second growth	19	11	1.7		
D. Concepcion, Bolivia (Davis 1993)					
Only forest	24	5	4.8	10.0	0.0015
Other habitats	13	19	0.7		
E. Madagascar (Langrand 1990)					
Only rain forest	18	10	1.8	3.9	0.049
Other habitats	24	37	0.6		
F. Colombia (Hilty & Brown 1986)					
Only rain forests	91	45	2.0	39.0	<0.000001
Other habitats	138	245	0.6		
G. Peru (Parker *et al*. 1982)					
Only rain forests	192	170	1.1	5.7	0.017
Other habitats	41	62	0.7		
H. Australia (Pizzey 1980)					
Only rain forest	10	1	10.0	15.9	0.00007
Other habitats	23	69	0.3		

Ecological Specialisation

In the forest, insectivorous birds are generally more specialised than other bird guilds. For this reason, they are more sensitive to subtle changes (Canaday 1997). As a result, insectivorous birds have developed numerous specialised niches and forage in certain narrowly defined microhabitats (Sekercioglu 2002). The high abundance of insects in Sarawak's forest causes insectivorous birds to hunt in a wide range of microhabitats but in particular niches (Fogden 1972). In the subtropical forest in Hong Kong, microhabitat utilisation differs between *Parus major* and *Sitta frontalis*. *P. major* frequently uses branches with a diameter of

less than 2 cm and primarily searches leaves whereas *S. frontalis* frequently uses branches with a diameter greater than 2 cm and has not been observed to search leaves (Kwok 2009). However, birds' foraging behaviour may show differential responses in disturbed areas (Lloyd 2008). The birds may compete more intensely with each other for the remaining resources in the disturbed areas.

Food Scarcity

Habitat loss removes certain invertebrates that may well be preferred by insectivorous birds (Ford *et al.* 2001). A decline of insectivores may occur in impacted habitats because of a reduction or lack of certain important forest elements, such as army ant swarms in Central and South America (Canaday 1997) or loss of termites. Vegetation clearance and the replacement of native vegetation by crops may change the composition of the seed and invertebrate resources (Ford *et al*. 2001).

Microclimate

Forest edges are affected by wind damage and by removal of loose bark, a microhabitat used by certain bird species (Ford *et al*. 1986). The drying and warming effects of vegetation clearing at the forest edge extends into the forest, and the rate of solar illumination is higher near the forest edge (Kapos 1989). It is believed that deforestation can lengthen the dry season and thus affect the insectivorous birds because the species diversity of tropical invertebrates is influenced by moisture (Levings & Windsor 1984).

Predation

Habitat alteration can also affect insectivores and may support predator species that hunt in different ways in the forest edge and the forest interior (Canaday 1997). Certain raptor species in the tropics have been found to exhibit different characteristics in disturbed habitats and undisturbed habitats (Thiollay 1985). Habitat loss can attract raptors to prey on juveniles, particularly in disturbed understory habitats (Priddel & Wheeler 1996).

Interspecific Competition

Insectivorous bird populations are affected by a number of other bird species. For example, the removal of *Manorina melanophrys* from disturbed habitats has caused an increase in the number of insectivores (Clarke & Schedvin 1997). Interspecific competition may also occur because the same resources are used by different bird species in the same resource-poor habitat (Ford *et al.* 2001).

Implications for Conservation

The results from this study are generally applicable to the conservation of the forest. Although cave systems were not explored in this study, it is adequate to perform studies of cave birds on limestone outcrops because the cave-dwelling birds forage outside the caves during the day. In the sites investigated in this study, the types of bird species recorded varied considerably with the distance from the artificially created forest edges. It is more important to focus on sensitive

species than on total species richness. For example, certain feeding guilds of bird species in this study were abundant in the disturbed area. These species exemplify species whose conservation requires relatively less attention.

The edge effects found in this study suggest that edges should not be created unnecessarily. In addition, the habitats that are already affected must be protected because their effects extend into the forest and affect its biodiversity. The forest-edge habitat is typically exposed to a variety of degradation-related problems, such as food scarcity, microclimate effects, predation on nests and juveniles, heightened interspecies competition, and the loss of specialised ecological niches. However, the processes by which sensitive species move from the disturbed areas require further investigation to maximise conservation outcomes.

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Appendix 1

List of bird species in Lenggong limestone area in three different zones; forest edge, forest intermediate and forest interior. Feeding guild; I: insectivores, F: frugivores, C: carnivores, O: omnivores, N: nectarivores, G: granivores.

Family / Species	Scientific name	Forest edge	Forest intermediate	Forest interior	Feeding guilds
Rallidae					
White-breasted Waterhen	*Amaurornis phoenicurus*	√	√		C
Columbidae					
Emerald Dove	*Chalcophaps indica*	√	√	√	G
Peaceful Dove	*Geopelia striata*	√	√		G
Psittacidae					
Blue-crowned Hanging-parrot	*Loriculus galgulus*	√	√		F
Cuculidae					
Plaintive Cuckoo	*Cacomantis merulinus*	√			I
Rusty-breasted Cuckoo	*C. sepulcralis*	√			I
Drongo Cuckoo	*Surniculus lugubris*		√	√	I
Greater Coucal	*Centropus sinensis*	√	√		C
Black-bellied Malkoha	*Phaenicophaeus diardi*	√	√		O
Red-billed Malkoha	*P. javanicus*	√	√		O
Raffles Malkoha	*P. chlorophaeus*	√	√		O
Chestnut-bellied Malkoha	*P. sumatranus*	√	√	√	O
Trogonidae					
Scarlet-rumped Trogon	*Harpactes duvaucelii*		√	√	I
Red-naped Trogon	*H. kasumba*			√	I
Alcedinidae					
White-throated Kingfisher	Halcyon smyrnensis	√	√		C
Blue-eared Kingfisher	Alcedo meninting	√	√		C
Meropidae					
Red-bearded Beeeater	*Nyctyornis amictus*		√	√	I
Chestnut-headed Beeater	*Merops leschenaulti*	√	√		I
Blue-throated Beeater	*M. viridis*	√	√		I
Bucerotidae					
Great Hornbill	*Buceros bicornis*		√	√	O
Rhinoceros Hornbill	*B. rhinoceros*		√	√	O

Family / Species	Scientific name	Forest edge	Forest intermediate	Forest interior	Feeding guilds
Ramphastidae					
Brown Barbet	*Calorhamphus fuliginosus*	√	√		F
Blue-eared Barbet	*Megalaima australis*	√	√	√	F
Red-throated Barbet	*M. mystacophanos*		√	√	F
Yellow-crowned Barbet	*M. henricii*		√	√	F
Gold-whiskered Barbet	*M. chrysopogon*		√	√	F
Picidae					
Maroon Woodpecker	*Blythipicus rubiginosus*		√	√	I
Orange-backed Woodpecker	*Reinwardtipicus validus*		√	√	I
Rufous Woodpecker	*Celeus brachyurus*		√	√	I
Grey-and-buff Woodpecker	*Hemicircus concretus*	√	√	√	I
Buff-rumped Woodpecker	*Meiglyptes tristis*	√			I
Buff-necked Woodpecker	*M. tukki*			√	I
Banded Woodpecker	*Picus mineaceus*		√	√	I
Common Flameback	*Dinopium javanense*		√	√	I
Rufous Piculet	*Sasia abnormis*	√	√	√	I
Eurylaimidae					
Black-and-yellow Broadbill	*Eurylaimus ochromalus*		√	√	I
Banded Broadbill	*E. javanicus*		√	√	I
Dusky Broadbill	*Corydon sumatranus*		√	√	I
Vireonidae					
White-bellied Erpornis	Erpornis *zantholeuca*	√	√	√	I
Campephagidae					
Black-winged Flycatcher-shrike	*Hemipus hirundinaceus*	√	√	√	I
Large Woodshrike	*Tephrodornis gularis*	√	√	√	I
Lesser Cuckooshrike	*Coracina fimbriata*	√			I
Ashy Minivet	*Pericrocotus divaricatus*	√	√	√	I
Aegithinidae					
Common Iora	*Aegithina tiphia*	√	√	√	I
Green Iora	*A. viridissima*	√	√	√	I

Family / Species	Scientific Name	Forest edge	Forest intermediate	Forest interior	Feeding guilds
Dicruridae					
Crow-billed Drongo	*Dicrurus annectans*			√	I
Greater Racket-tailed Drongo	*D. paradiseus*	√	√	√	I
Monarhidae					
Black-naped Monarch	*Hypothymis azurea*		√	√	I
Asian Paradise-flycatcher	*Terpsiphone paradisi*		√	√	I
Laniidae					
Tiger Shrike	*Lanius tigrinus*	√	√		C
Brown Shrike	*L. cristatus*	√	√		C
Muscicapidae					
Magpie Robin	Copsychus saularis	√	√		I
Tickell's Blue Flycatcher	Cyornis tickelliae	√	√	√	I
Yellow-rumped Flycatcher	Ficedula zanthopygia		√	√	I
Asian Brown Flycatcher	Muscicapa dauurica		√	√	I
Blue Whistling-thrush	Myophonus caeruleus		√	√	O
Pycnonotidae					
Yellow-vented Bulbul	*Pycnonotus goiavier*	√			O
Red-eyed Bulbul	*P. brunneus*	√	√	√	F
Stripe-throated Bulbul	*P. finlaysoni*	√	√	√	F
Black-headed Bulbul	*P. atriceps*		√	√	F
Cream-vented Bulbul	*P.simplex*	√	√	√	F
Spectacled Bulbul	*P. erythropthalmos*	√	√	√	F
Black-crested Bulbul	*P. melanicterus*		√	√	F
Scaly-breasted Bulbul	*P. squamatus*	√			F
Olive-winged Bulbul	*P. plumosus*		√	√	F
Buff-vented Bulbul	*Iole olivacea*	√	√	√	F
Hairy-backed Bulbul	*Tricholestes criniger*		√	√	I
Phylloscopidae					
Arctic Warbler	*Phylloscopus borealis*		√	√	I
Eastern-crowned Warbler	*P. coronatus*			√	I

Family / Species	Scientific name	Forest edge	Forest intermediate	Forest interior	Feeding guilds
Timaliidae					
Abbott's Babbler	*Malacocincla abbotti*	√	√	√	I
Short-tailed Babbler	*M. malaccensis*		√	√	I
Grey-throated Babbler	*Stachyris nigriceps*		√	√	I
Chestnut-winged	*S. erythroptera*	√	√	√	I
Grey-headed Babbler Babbler	*S. poliocephala*	√	√	√	I
Pin-striped Tit-babbler	*Macronous gularis*	√	√	√	I
Puff-throated Babbler	*Pellorneum ruficeps*		√	√	I
Sooty-capped Babbler	*Malacopteron affine*		√	√	I
White-rumped Shama	*Copsychus malabaricus*		√	√	I
Everett's White Eye	*Zosterops everetti*		√	√	I
Cisticolidae					
Yellow-bellied Prinia	*Prinia flaviventris*	√	√		I
Rufescent Prinia	*P. rufescens*	√			I
Common Tailorbird	*Orthotomus sutorius*	√			I
Species total		58	83	71	
Confined to single forest zone		11	1	5	
Insectivores		25/52	41/52	41/52	
Frugivores		15/24	21/24	20/24	
All other diets		18/24	21/24	10/24	