Above-ground Space Utilization and Feeding Guild of Tropical Rainforest Birds in Sarawak, Borneo

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ABSTRACT Above-ground space within tropical rainforests harbour many bird species. However, the mechanism for their coexistence remains largely unknown. Avian feeding guilds are known to be good indicator of habitat specialization, but the details of how bird use of above-ground space, especially in reference to feeding remain unclear. Double-stacked mist-nets, with a total of six shelves and extending up to 3.6 metres above ground, were deployed at 30 forest sites in the Baram, Baleh and Pelagus regions of Sarawak, Borneo (East Malaysia). A total of 2,613 birds, comprising 124 species, were captured. Eight feeding guilds were identified, with insectivores being the most abundant. Most birds were captured at shelf 3 and 4, equivalent to 1.2 to 2.4 metres above-ground. Both the number of species and individuals captured in the shelves increased from the ground upwards to reach a maximum at shelf 3, after which it decreased. Insectivores were the most common guilds at the lowest two shelves, accounting for 68 % in shelf 1 and 47 % in shelf 2. This study shows that tropical forest birds are able to coexist in the relative safety of the above-ground space by exploiting different food resources indicating the importance of feeding guild in determining vertical stratification of avifauna species.

KEYWORDS: Tropical birds, vertical stratification, mist nets, feeding guild, insectivores, Sarawak

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TRANSACTIONS ON SCIENCE AND TECHNOLOGY

INTRODUCTION

The bird community in Borneo is made up of 674 species (Lepage, 2017), comprising both resident and migratory taxa. The habitats for birds in Borneo range from mangrove forests along the coastal areas, to the montane forests above 1000 m ASL (Phillipps & Phillipps, 2014). The variety of bird community inhabiting the different forest types is a consequence of the different resources supplied by each habitat. Habitat-specialised species, such as egrets and herons, occur in areas adjacent to waterbodies, while montane species, such as the Mountain Black-eye, occurs on highlands above 1000 m ASL. Comparatively, lowland forested areas would contain higher concentration of bird in the tropic due to the sufficiency and variety of food resources (Rahman & Tuen, 2006; Mansor *et al*., 2011; Nurul Ashikeen *et al*., 2015).

Assemblages of birds in relation to their feeding guild have been widely studied. Previous findings reported that habitats dominated by insectivores varies and range from secondary forests, oil palm plantations, subtropical land-bridges islands to coastal areas (del Rio, 2001; Azman *et al*., 2011; Pineda-Diez *et al*., 2012; Ding *et al*., 2015; Rathod *et al*., 2015). Other studies reported that insectivores and frugivores were negatively affected by logging but nectarivores and granivores were positively affected (Burivalova *et al*., 2015). Granivores associate more with anthropogenic activities, as seen from their occurrences at paddy field (Azman *et al*., 2011; Azman *et al*, 2012).

In the studies of vertical stratification of avifauna species and their feeding guilds, above-ground space is typically defined as the vegetated area from the ground up to about 2 meters. Above

the 2 meter mark up to the main canopy there is a relatively clear space which is referred to as the understorey. Birds that occupy the above-ground and understorey are either unaffected or positively affected by anthropogenic activities compared to birds inhabiting higher strata and canopy of tropical rainforest (de Iongh & van Weerd, 2007; Mallari *et al*., 2011; Restrepo & Gomez, 1998). How these birds partitioned themselves within the above-ground and understorey space and the role of how food distribution in this space influence feeding guild have not been clearly discussed (de Iongh & van Weerd, 2007).

Studies using mist nets set at the canopy (Rahman, 2002) have shown seven families, such as Cuculidae, Capitonidae, Eurylaimidae, Campephagidae, Chloropseidae, Dicruridae and Oriolidae inhabit the canopy, and are rarely captured in the understorey. Vertical stratifications were also seen among some sympatric interspecies communities. For example, Kumar *et al*. (2009) reported that migratory birds were found perching at the branches of the same tree at different height above ground. Pygmy Nuthatches, Brown Creepers and White-breasted Nuthatches were seen occupying different heights on the tree, on thin branches, thick branches and at the lower trunk (Lara *et al*., 2015). This behaviour shown by the birds promotes the coexistences among sympatric interspecific bird community. Among babblers, Abbott's Babblers was found using the area from the ground up to four metres high and Chestnut-winged Babblers did not use ground area only but has a wider range which was from ground up to 12 metres above ground (Mansor *et al*., 2015).

The studies referred above have only looked at the use of above-ground space and made no attempt to link vertical space use with their feeding guild. The objective of this study was to determine the space partitioning by birds in the above-ground space more accurately by trapping them using mist nets, and to determine if the vertical stratification in the understorey was based on feeding guild or species *per se.*

METHODOLOGY

Study Sites

Table 1. Brief description of habitat types at the sampling site.

	Habitat type	Description
1	Secondary forest	Trees not tall (< 20 m), small in diameter (<30 cm dbh). Denser vegetative cover. Macaranga trees abundant.
2	Logged-over forest	Signs of recent logged and skid trails used for transporting log. Large trees occasionally seen emerging from surrounding canopy of smaller trees. Large canopy gaps with regenerating vegetative cover.
3	Agroforest	Planted fruit trees were frequently encountered. Usually close to human settlements.
4	Primary forest	Abundance of emergent trees, > 50 cm in diameter, canopy reaches 40-50 metre. Relatively clear understorey. Dipterocarp trees common.

The present study was conducted at Pelagus, Upper Baram and Baleh River Basin in Sarawak, Borneo, within a total of 30 sites, with 10 sites chosen from each area. The avifauna habitats at these sites were mainly made up of degraded forests, including regenerated secondary forests, logged-over forests and agroforests. Only three sites are primary forests. The description of visited site is shown in Table 1. A common feature of these habitats is the dense vegetative cover made up of

grass, ferns, shrubs and small trees up to about 2.5 meters above ground, proceeded by a relatively sparse space to the main canopy above.

Data Collection

Eight stacked nets were deployed at each location randomly. Stacked nets are two single nets with same length (9 m) that were joined together by tying the bottom lead line of the second net to the top lead line of the first net. The nets were erected using telescopic aluminum poles such that the bottom of the first net touched the ground. The highest point of the shelf was 3.6 metres high and each shelf was 0.6 metres high when the nets were opened with allowance for pockets at each shelf. Stacked-nets were deployed for four days at each site and relocated occasionally in order to maximise the capture rate of the bird.

Shelf number of each bird trapped in the net was recorded. All birds caught in the nets were identified using Phillipps & Phillipps (2014) and confirmed with Avibase – The World Bird Database available on http://avibase.bsc-eoc.org/checklist.jsp?region=BOR&list=howardmoore. Each individual bird was measured, weighed, ringed and released (Rahman, 2002; Mansor *et al*., 2011)

Avian feeding guild was defined as a group of birds exploiting similar food resources in the same way (Root, 1967; Poulin *et al*., 1994). In this study, the captured birds were grouped into eight feeding guilds (Table 2) in accordance to information given by Myers (2009) and Phillipps & Phillipps (2014) for Bornean birds.

Table 2. Definition of avian feeding guilds (adapted from Myers (2009) and Phillipps & Phillips (2014)).

Feeding guilds	Definitions
Insectivore	Birds that feed exclusively on arthropods including insects.
Nectarivore	Birds that feed exclusively on nectar of flowers.
Frugivore	Birds that feed exclusively on fruits on tree or ground.
Carnivore	Birds that feed exclusively on small mammals, birds or fish
Granivore	Birds that feed exclusively on grains or seeds from the plant or on the ground
Frugivore-Insectivore (Fru-Ins)	Birds that feed primarily on fruit but shift to insects when fruit volume are low at certain period of time
Carnivore-Insectivore (Car-Ins)	Birds that feed primarily on small mammals, birds or fishes but shift to insects when the former are low at certain period of time.
Insectivore-Frugivore (Ins-Fru)	Birds that feed primarily on insects but shift to fruits when insects are low at certain period of time.

Statistical Analysis

The number of birds caught was compared using a Chi-square test. Space utilisation was based on the number of shelf birds trapped in the net, analysed using a principal component multivariate analysis (PCA) using the software PAST (Hammer & Harper, 2006).

RESULT AND DISCUSSION

Altogether, 2,613 encounter frequencies of bird, representing 124 species and 31 families were recorded from this study (supplementary data available upon request). Nectariidae is the most speciose family with 16 species captured, followed by Muscicapidae, Pycnonotidae, Pellorneidae and Timaliidae with 15, 13, 10 and 8 species, respectively. Ten families that were recorded with a single species include Columbidae, Podargidae, Accipitridae, Indicatoridae, Psittaculidae, Calyptomenidae, Vangidae, Corvidae, Phyllospidae and Zosteropidae.

Of the six shelves, Shelf 3 was the most productive, capturing 725 counts of bird whereby the least productive was Shelf 6 with only 168 counts (Figure 1). The number of catches increased from shelf 1 to 3 but then declined to shelf 6. Chi-square test result shows that there is a significant difference ($p < 0.01$) between the numbers of individuals captured at each shelf.

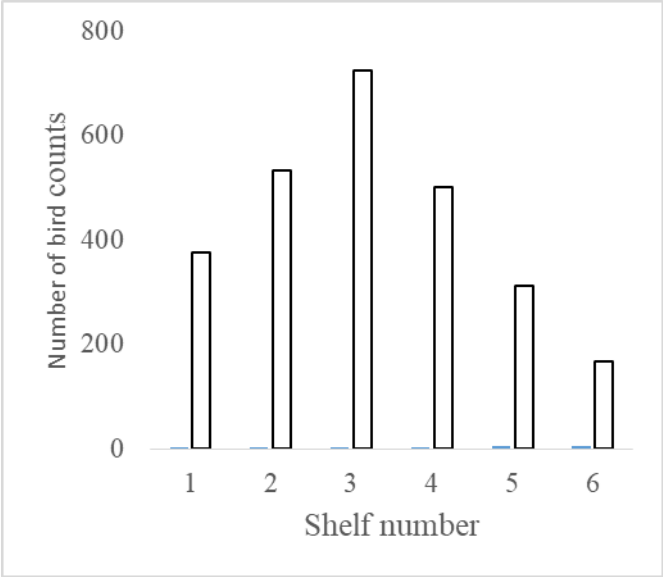


Figure 1. Total counts of birds trapped in accordance to shelf at different height above ground at the stacked mist-nets that deployed in this study.

The result of multivariate analysis (Figure 2) also shows that a majority of the bird species were caught shelf 3 and 4 equal to height of 1.2 m – 2.4 m above-ground. Less birds and species use the space close to the ground, represented by shelf 1 and 2 (< 1.2 m above-ground) or higher up represented by shelf 5 and 6 (> 2.4 m above-ground). Figure 2 also shows that Little Spiderhunter (LS) most likely to be caught at shelf 3, while Short-tailed Babbler (STaB) and Chestnut-winged Babbler (CWB) are most likely to be caught closer to the ground at Shelf 1 and 2.

Birds are likely to use space which provides protection from predators, food resources and services such as perching and nesting sites (Tuen & Brown, 1996). Forest structure that consists of dense above-ground vegetation, clear understorey and dense foliage at the canopy are expected to be occupied at different densities and by different species and guilds.

The increasing number of individuals trapped from shelf 1 to shelf 3 indicates that the space at from forest floor to 1.8 m above-ground were mostly preferred and utilised by the bird. At this height above-ground, the dense vegetative cover due to growing trees, bushes and ferns serve as a refuge from predators for small birds. Birds that hop, such as babblers, are found mainly at these layers where plant growth is dense. In contrast, the decreasing of the number of the individuals captured at shelf 4 to 6 implies less space utilisation at this height as it was a relatively clear area.

This space suit strong and fast-flyers, such as dove, broadbill and others (Phillipps & Phillipps, 2014). The relatively uncluttered space from 1.8 m above-ground to the main canopy do not provide much refuge from predators, such as raptors and owl, and are therefore, less-frequently used by birds until it reaches the canopy where the foliage and branches again serve them by providing places to perch, rest and build nests.

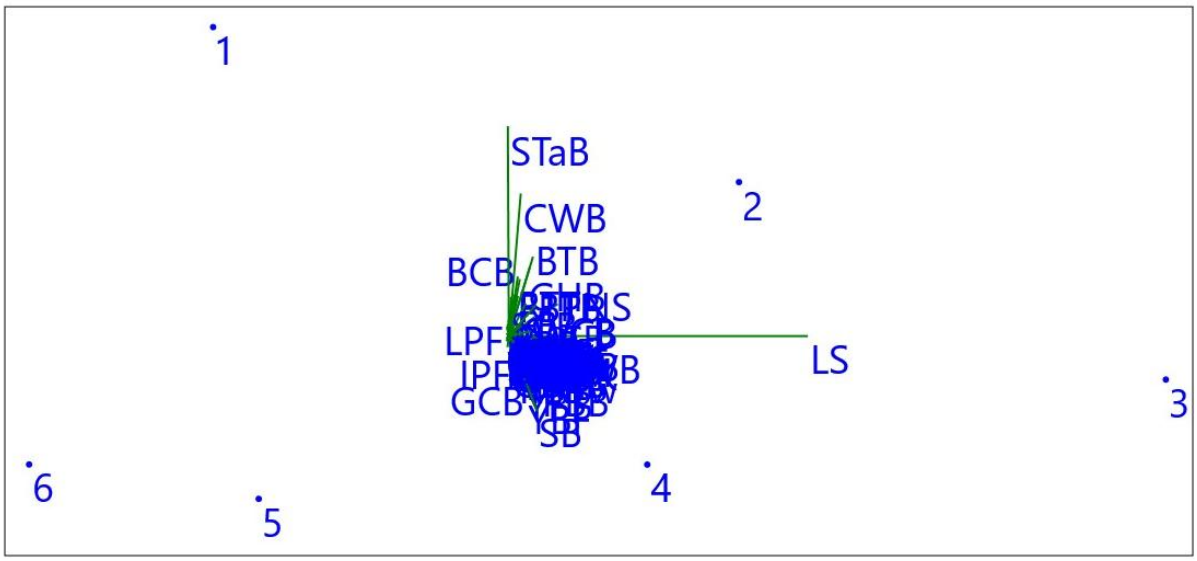
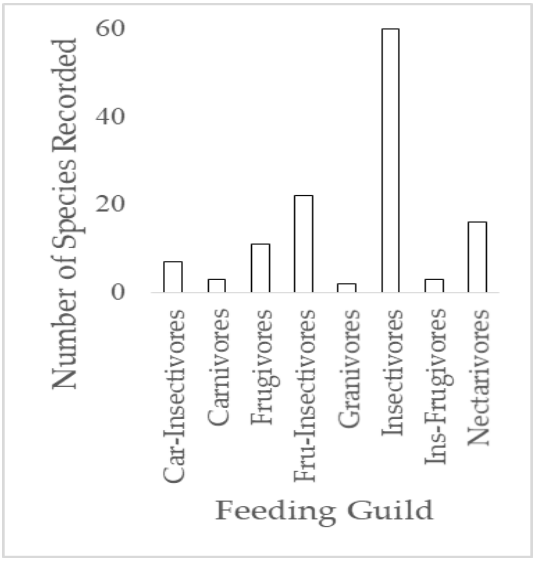
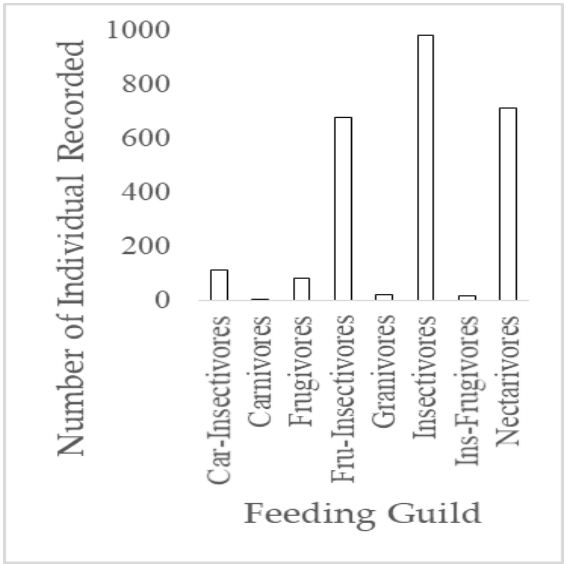


Figure 2. Majority of birds in this study caught in the at shelf number three and four. Each dot and its number represent the shelf of nets. Abbreviations in blue are the code of birds.

Insectivores was the most common guild, with 59 species and 915 captures, followed by nectarivore and frugivore-insectivore with 16 and 22 species and 715 and 681 catches, respectively (Figure 3 and 4).





Figures 3 (left) and 4 (right). Total number of species and individuals in accordance to the feeding guilds recorded from the study sites in Sarawak, Borneo.

Most guilds were found and guild members trapped at shelves 2, 3 and 4, equivalent to 0.6 m to 2.4 m above-ground (Figure 4). Insectivores are mostly caught at shelves 1 and 2 (accounting for 68% shelf 1 and 47% in shelf 2), nectarivores are mostly caught at Shelf 3 and frugivores-insectivores are mostly caught at shelf 4. Chi-square results show that the individuals of all guilds captured

among shelves are significantly different, except that of carnivores and granivores. The percentage of insectivores decreased from 1 to 6, while that of frugivores-insectivores increased.

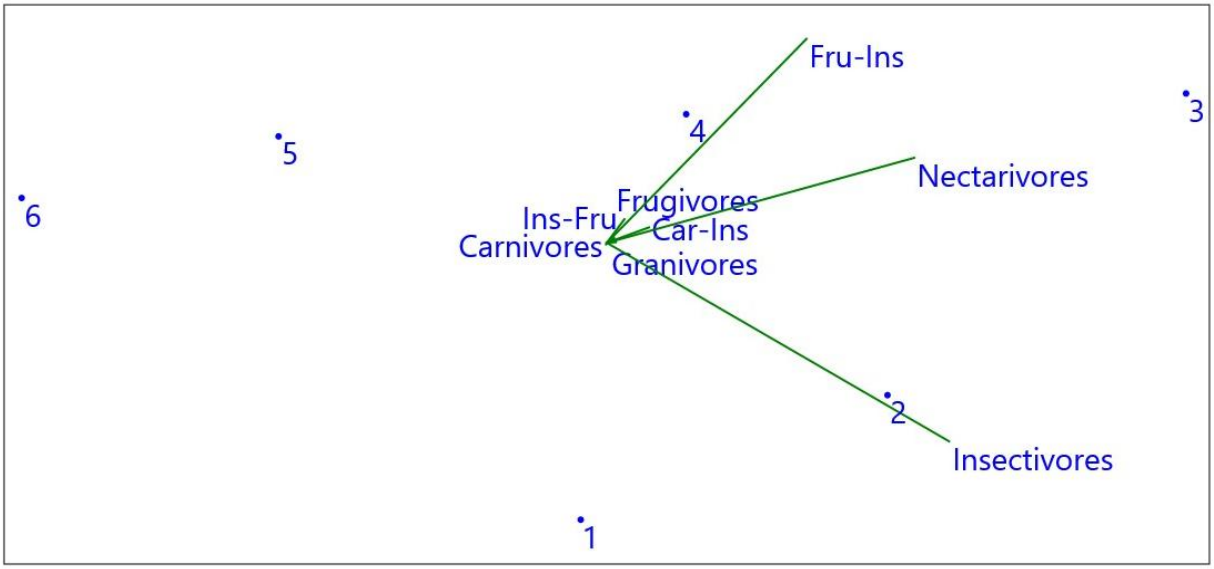


Figure 4. The majority of feeding guilds of bird from the study sites were trapped frequently at shelves 2, 3 and 4.

As for other guilds, they utilised the spaces more evenly. More birds of frugivores-insectivores guilds use the space between 2.4–3.6 metres above ground, equivalent to shelves 4-6. Nectarivores used all spaces more evenly except areas near ground (shelf 1). Guilds such as the carnivores-insectivores, carnivores, frugivores, granivores and insectivores-frugivores were found occupying all the space up to 3.6 metres, however the number of individuals captured were relatively small.

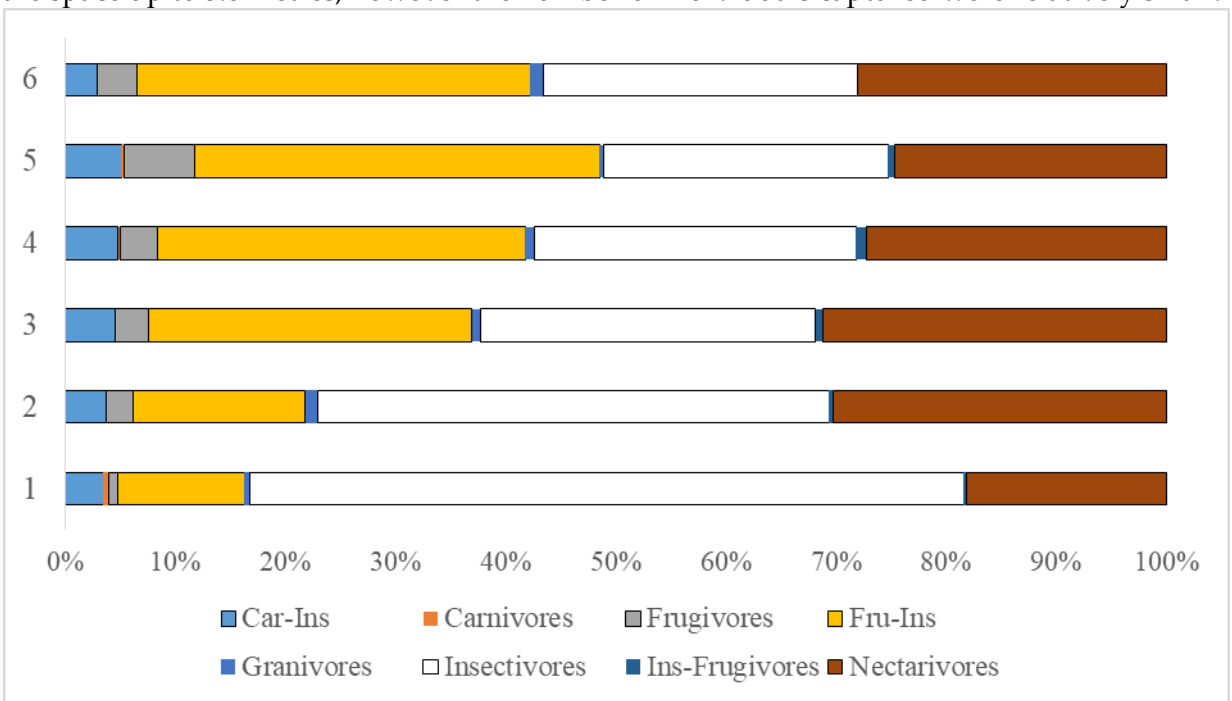


Figure 5. Total percentage of bird feeding guilds based on individual captured at respective shelf.

Eight feeding guilds, comprising 124 bird species, were recorded at the understorey at 0–3.6 m above-ground space in all study areas (Pelagus, Upper Baram and Upper Baleh). The concentration of high species in above-ground space could also be due to the availability of food resources. For example, insects are diverse and abundant on the forest floor and therefore insectivores should

follow suit. Volant and crawling insects of both forest floor and tree barks could be an easy food for guilds that are obligate or partial-obligates, feeding on insects.

Of all guilds, insectivores were captured mostly at the lower shelves, 1 and 2. This indicates that this guild mostly use the forest floor and spaces near to it. Babblers, for one were found dominated at both shelves might be due to their preference for foraging at the forest floor (Anthal & Sahi, 2013; Mansor *et al*., 2015; Styring *et al*., 2016). Their foraging pattern on the forest floor, as mentioned in Mansor *et al.* (2015), include probing dead leaves on the ground, could be the reason for their entrapment at shelves 1 and 2. Moreover, the species of this group hop from branch to branch at the level where vegetation was dense.

Other guild members, such as the Nectariidae, were mainly caught in shelves 3 and 4 which imply that the utilisation of space was different from that of the insectivores. Nevertheless, Figure 5 shows that this guild had a similar proportion at each shelf, implying they use the space similar with others. One of the nectarids, Little Spiderhunter (*Arachnotera longistra*) was found to be using larger space understory and was encountered at all shelves, which could be due to its food sources- ginger flowers and other flowers that provide nectar that are probably distributed within 3.5 metre of the forest floor.

Guilds like frugivores-insectivores and insectivores-frugivores that were captured more on shelf 3 and above shows that they utilise less space at the ground-level of the forest than insectivores. These guilds, consisting of species with relative larger body size such as members of the families Trogonidae, Rhampatisdae and Corvidae (except Dicaceidae) were recorded more often at above-ground 1.2 m, possible because fruits are scarce on the ground.

CONCLUSION

The occurrence of birds is highest at height of 1.2–1.8 m above-ground. Most guilds generally utilise spaces up to 3.6 m above ground, however insectivores were found most abundant closer to the ground. In contrast, less frugivores-insectovores were recorded closer to the ground but their numbers increased with increasing height. It seems that the dense vegetative cover closer to the ground not only offered protection from potential predators but also provided abundant food resources especially to insectivores. This suggested the importance of feeding guild as possible mechanism that determines vertical stratification of avian species in tropical forest.

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