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Diversity of bird-feeding guilds in Bukit Mas Village, North Sumatra, Indonesia

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Abstract. *Husna F, Nurhayati, Patria MP, Winarni NL. 2024. Diversity of bird-feeding guilds in Bukit Mas Village, North Sumatra, Indonesia. Biodiversitas 25: 4572-4580.* Birds are one of the essential components of the ecosystem. Like other organisms, birds provide significant services to maintain the balance of the ecosystem. Resource availability in different habitats may lead to differences in the composition of bird functional groups, such as feeding guilds. We conducted research to analyze differences between bird-feeding guilds of three habitats: residential areas, plantations, and forest edges. The research was conducted in Bukit Mas Village, Besitang District, North Sumatra, Indonesia. The village is one of the areas directly adjoining Gunung Leuser National Park. The observation was carried out from August to September 2023. Observation was conducted using the point-count method with a 100 m radius for 10 minutes. Sixteen observation points (150-200 m distance per point) were placed in residential areas and plantations, and eight observation points were placed in forest-edge. A total of 87 species and 1,703 individual birds were sighted within the observation, with the highest number found in residential habitats. The highest Shannon Diversity Index (SHDI) is found in forest edge habitat (H'=3.25), followed by plantation (H'=3.17) and residential habitat (H'=2.86). Extrapolation using the iNEXT package shows higher diversity in forest edge as well. The most abundant feeding guild found in the residential habitat were omnivores, while the commonest feeding guild in the plantation habitat were insectivores. In the forest edge habitat, the most abundant feeding guild was insectivore-frugivores. The forest edge habitat also has different least common feeding guilds, having three least feeding guilds, including piscivores, granivores, and insectivore-piscivores. NMDS analysis shows a closer similarity between residential areas and plantations based on species richness and a closer similarity between plantation and forest edge based on feeding guilds. Our result shows a negative correlation between canopy coverage and several feeding guilds. However, the correlation between understory coverage and some feeding guilds shows positive results. It might occur due to the foraging behavior of some birds from particular guilds. The variety of resources and feeding guilds found in different habitats suggested the importance of these habitats and the need to manage them as a landscape for protecting bird diversity.

Keywords: Bird diversity, Bukit Mas Village, feeding guild, North Sumatra, point count

INTRODUCTION

Birds are one of the essential components of an ecosystem, as they provide helpful, and significant services to maintain the balance of the ecosystem (Şekercioğlu et al. 2004). Birds are sensitive to habitat changes (Hadinoto et al. 2012). They can be used as an indicator to recognize habitat quality, level of degradation, and restoration of an area. Differences in bird composition are influenced by several factors. Vegetation structure creates a heterogeneous habitat and is highly correlated with the abundance of birds (Matsuba et al. 2016). Forest habitats with more complex vegetation structures support higher bird diversity than plantation areas (Dinanti et al. 2018). The number of birds living in a habitat is also influenced by canopy cover and the proportion of old trees. Old trees with holes are commonly used as nests by certain birds. It can add to the richness of bird species living in the habitat (Tworek 2007). Similarly, dead trees could also affect bird diversity due to a nesting site and diverse sources of food (Atikah et al. 2021).

A functional group is a group of living things that utilize the same resources (O'Connell et al. 2000). Bird functional groups, such as feeding guilds, can be used to detect changes in bird communities, as the availability of food resources influences the composition of birds in a habitat (Arriaga-Weiss et al. 2007). The relationship of bird functional group responses to different habitats has been studied in various locations. Arriaga-Weiss et al. (2007) stated that carnivorous birds generally utilize large habitat fragments. Sadam et al. (2021) reported that birds in plantation areas generally have a lower specialist species but high species richness due to landscape heterogeneity. Extensive tree canopy cover provides better quality habitat for specialist birds (Gebremichael et al. 2022). Fragmentation and edge effects also affect the distribution of bird communities in a habitat. Generalists are found near forest edges, while the frequency of forest specialists increases at distances of 150 m or more away from forest edges (Hofmeister et al. 2017). Winarni et al. (2019) reported that the presence of forest edges in Bukit Barisan Selatan National Park, Indonesia tends to support mixed

flocks of different species. It occurs due to the more complex vegetation structure of the forest edge more diverse resources for the bird community. Differences in vegetation structure and type in different habitats will affect the abundance of bird functional groups found in a particular habitat. All guilds will respond to the environment differently since every guild has different responses toward environmental factors (Katuwal et al. 2016).

Forest edges usually support a high bird richness due to the heterogeneity of feeding and nesting habitats (van Halder et al. 2011). Mohd-Azlan et al. (2019) found that bird diversity values at the edge of forest fragments in Sarawak were higher when compared to forest interiors and gardens. It is because birds found at the edge of the forest are a mixed group of birds found in both forests and plantations. Winarni et al. (2019) also reported that groups commonly found at forest edges consist of edge specialists, forest interior specialists, and garden interior specialists. The presence of various bird groups in forest edges shows the importance of particular habitats as a support for bird feeding guild diversity. However, forest edges are vulnerable to deforestation due to their accessibility. Deforestation pressures still occur at various points in Gunung Leuser National Park (Lubis et al. 2019). Higher pressure in forest edges may lead to a decline in the diversity of birds in these habitats, particularly insectivores and frugivores vulnerable to deforestation (Gray et al. 2007). Some forest edges in Gunung Leuser National Park, Indonesia are adjacent to human-modified habitats, such as plantations and farmland. The changes in particular habitats might affect the bird community in forest edges. Therefore, in this study, we compare the bird diversity between different habitat types along the park boundary, such as forest edge, plantation, and residential areas. We also evaluate the dissimilarities of the bird community among the habitats.

MATERIALS AND METHODS

Study area

Surveys were conducted in Bukit Mas Village, Besitang District, North Sumatra, Indonesia (Figure 1). The village is one of the areas directly adjoining Gunung Leuser National Park. We conducted this study in three habitat types: residential area, plantation, and forest edge habitats (Figure 2). The residential area is generally dominated by buildings such as schools, stalls, and housing. Each building usually has a yard with fruit-bearing plants, such as orange and rambutan trees. Locals also grow herbs that could be used as medicinal plants, such as ginger and turmeric (Nasution et al. 2016). The plantation habitat consisted of oil palm plantations belonging to the local residents. Palm trees and other plants are also found along the edge of the plantation. On the forest edge habitat, we conducted the observation along the border of Gunung Leuser National Park at a distance of approximately 150 m to the edge of the park. Observations were carried out during August-September 2023. We used point counts with a 100 m radius and 10 minutes of observation time (Bibby et al. 1998). Sixteen observation points, with 150-200 m distance between points, were placed in residential areas and plantations. We observed eight points at the forest edge. We conducted counts from 0600 to 1000 hrs. We recorded the species and the number of individuals seen and heard at each point.

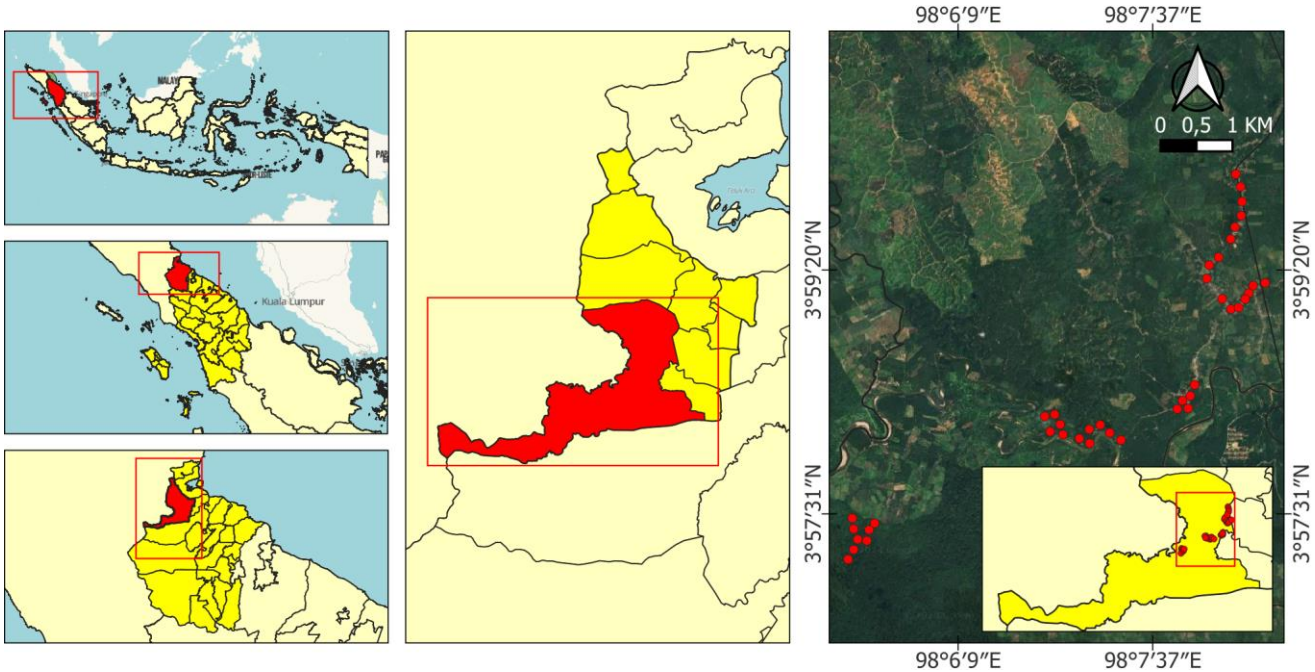

Figure 1. Map of points observed in Bukit Mas Village, Besitang Sub-district, Langkat, North Sumatra, Indonesia

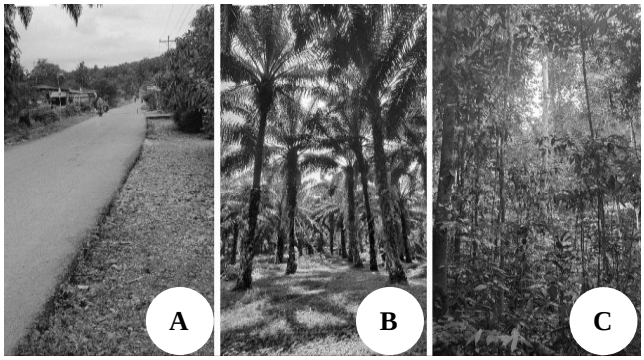

Figure 2. Three habitat types were observed in Bukit Mas Village, North Sumatra, Indonesia. A. Residential habitat, B. Plantation habitat, and C. Forest edge habitat

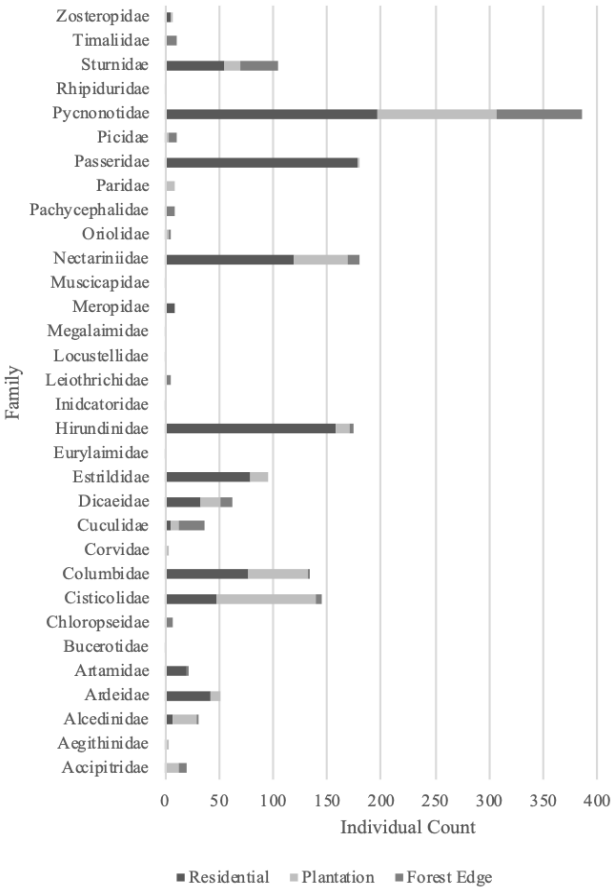

Figure 3. Families were observed in three different habitats. The graph shows Pycnonotidae as the most common family in the three habitats

Procedure

We used Nikon Prostaff binoculars with 8x42 magnification for identification. We identified the bird species based on MacKinnon et al. (2010) and Eaton et al. (2021). We also used several web-based checklists, such as Cornell Lab of Ornithology (https://birdsoftheworld.org/). Based on the above literature, we determined each species' feeding guild.

Data analysis

Shannon-Wiener index describes information about species richness based on the number of individuals of each species and their distribution (Magurran 2004). Shannon-Wiener diversity index is expressed by:

$$H = \sum pi.\ln pi$$

The value of pi is the proportion of individuals of species i and is obtained from the formula ni/N. The ni value is the number of individuals recorded at the observation point, while the N value is the total number of all individuals encountered.

For a clearer view of differences in diversity across habitats, diversity data were projected using extrapolation with the iNEXT package (Hsieh et al. 2016). We calculated the relationship between coverage (canopy and understory) and feeding guilds using the Spearman correlation. We also analyzed each habitat's dissimilarities according to species distribution and feeding guilds using Non-Metric Multidimensional Scaling (NMDS) with the vegan package in R version 2.3-0 (Okansen 2015). The purpose of using this analysis is to calculate the distance dissimilarities between three habitats using a low-dimensional space (Oksanen et al. 2015), illustrating a simpler picture of the relationship and possible overlap between birds from different habitats.

RESULTS AND DISCUSSION

Bird diversity and abundance

We observed a total of 87 species and 1,707 individuals. The highest number of species were observed in the forest edge (49 species), followed by the plantation (44 species) and residential habitat (40 species). The highest number of individuals were observed in the residential habitat (1040 birds), followed by the plantation (440 birds) and forest edge t (227 birds). The most abundant family was Pycnonotidae (Figure 3), with 15 species and 385 individuals sighted. Each habitat had different species with the highest relative abundance. In the residential habitat, *Passer montanus* (Linnaeus, 1758) was the most abundant (17%), followed by *Pycnonotus goiavier* (Scopoli, 1786) (15%). In the plantations, *Orthotomus ruficeps* (Lesson, 1830) was the most abundant (13.18%), followed by *P. goiavier* (11.81%). On the forest edge, *Aplonis panayensis* (Scopoli, 1786) was the most abundant species (15%), followed by *P. goiavier* (9%). We also found several threatened species according to the IUCN classification (2020), such as *Pycnonotus zeylanicus* (Gmelin, 1789), *Acridotheres javanicus* (Cabanis, 1851) and *Buceros rhinoceros* (Linnaeus, 1758).

This study found the highest number of bird individuals in residential habitats. It is consistent with Tu et al. (2020), which shows that rural built-up areas significantly increased the number of birds found within the habitat. While food availability for certain species may be plentiful in residential habitats (Hadinoto et al. 2012), natural habitats, such as forest-edge, may reduce the number of

birds sighted. It also goes in line with the result of our research, as we only found 227 individuals of birds in forest-edge habitats. Our research also showed that the most species was found in forest-edge habitats. It might happen because natural habitats usually promote higher species richness (Tu et al. 2020). Extrapolating the results with the iNEXT package provides a clearer picture of the diversity and abundance in the three habitat types. Per the diversity index calculation, the forest-edge habitat showed higher diversity, although the abundance was much lower compared to other habitats (Figure 4).

According to Table 1, forest edge habitat has the highest Shannon Diversity Index, SHDI (H=3.25). Since SHDI indicates high diversity if the value H'>3 (Setyono and Himawan 2018), we could conclude that the forest edge had a higher bird diversity value than other habitats. It goes in line with previous research, stating that natural habitats have higher diversity compared to man-modified habitats (Ayat and Tata 2015; Tu et al. 2020). Higher bird diversity value could be interpreted as higher vegetation complexity in said habitat. Complex vegetation structures may provide abundant and diverse food sources, which promote the diversity of birds (Shafie et al. 2022). Also, bird diversity is usually higher in habitats with higher stages of succession, such as in the forest (Nugroho et al. 2023). The vegetation on the forest edge is complex and filled with higher shrub richness and diverse plants (Alignier et al. 2014). The complex vegetation structure would provide more niches for nesting and foraging (Ouin et al. 2015) and promote bird richness (Huang et al. 2014; Moudrý et al. 2021; Remeš et al. 2022). Reducing the complexity of vegetation structures, such as forest conversion to plantations, would significantly reduce bird diversity (Subasinghe et al. 2014).

In all habitats combined, Pycnonotidae had the highest abundance. It may occur because of their adaptability. Pycnonotidae consists of many generalist species found throughout several continents, such as in Southeast Asia and Africa (Shakya and Sheldon 2017). They are usually found in various habitats and are important in maintaining the ecosystem (Ponpithuk et al. 2020). Their diet is also very diverse, as some species are known to eat insects and fruits (Eaton et al. 2021). As previously stated, despite not being the most abundant birds found in each habitat respectively, Pycnonotidae members are sighted often, having the second-most relative abundance in the three habitats. *P. goiavier*, for example, can be found across all three habitats and has the second-most relative abundance in residential areas, plantation, and forest-edge habitats, respectively.

The *P. montanus* (Family Passeridae) is the most abundant species in the residential habitat. This bird is usually associated with humans, often foraging for insects and seeds on the ground (MacKinnon et al. 2010). Anthropogenic activities provide plenty of food availability in residential habitats, which explains why certain birds live in specific habitats (Hadinoto et al. 2012). The *O. ruficeps* is plentiful in the plantation habitat, possibly because the species is a generalist. While *O. ruficeps* are generally found in other habitats such as open forests, forest edges, mangrove forests, seaside bushes, gardens, secondary vegetation, and bamboo groves (MacKinnon et al. 2010), *O. ruficeps* is usually more abundant in agricultural land, mixed garden land cover, and plantation forest land cover (Withaningsih et al. 2020). It occurs because agricultural lands tend to support the presence of some insects (Panda et al. 2021), which is *O. ruficeps* primary source of food.

Table 1. Comparison of abundance and Shannon Diversity Index (SHDI) in residential area, plantation, and forest edge habitats. The residential area had the highest abundance, while the forest edge had the highest value of SHDI

Habitat type	Abundance	SHDI (Shannon Diversity Index)
Residential area	1040	2.86
Plantation	440	3.17
Forest edge	227	3.25

Note: High (H' > 3); moderate (1 < H' ≤ 3); low (H' < 1)

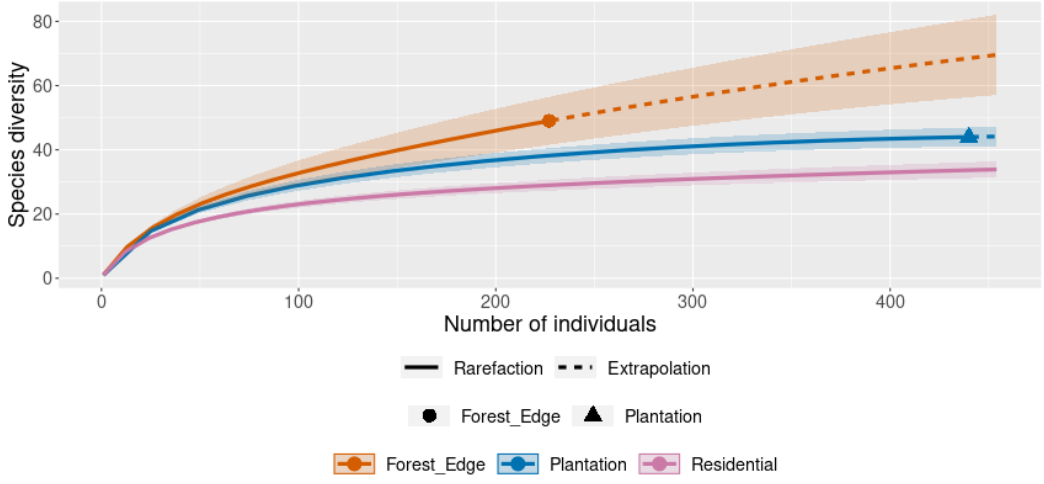

Figure 4. Species accumulation curve for three different habitats using the iNEXT package. According to the graph, forest edge habitat has higher diversity than other habitats

A. panayensis is the most abundant species found in the forest edge habitat. The *A. panayensis* primarily eat fruits like berries and figs (Hashim et al. 2021). Several such tree species were present in the forest edge (e.g., *Ficus fulva* Reinw. ex Blume, *Balakata baccata* (Roxb.) Esser, *Pternandra echinata* Jack, and *Chloranthus erectus* (Buch.-Ham.) Sweet). These tree species may be a source of food for *A. panayensis*, explaining their abundance on forest edge. However, *A. panayensis* also eats insects, sometimes joining mixed-flock species with other insectivores. They also visit open areas near forests, such as plantations, villages, and cities (MacKinnon et al. 2010).

Bird feeding guilds

The most abundant feeding guild found in all habitats combined were omnivores, followed by insectivores. Omnivores were also the most common feeding guild found in residential habitats, while insectivores were commonly found in plantation habitats (Figure 5). In forest edge habitat, the most abundant feeding guilds were insectivore-frugivores. The least common feeding guild found in all habitats combined were piscivores. Piscivores were also the least common feeding guild found in residential areas and plantation habitats. The forest edge habitat had three feeding guilds: piscivores, granivores, and insectivore-piscivores, which were the least common.

Omnivores are the most common feeding guild found in the three habitat types, especially in residential habitat. It is consistent with previous studies stating that omnivorous guilds are often found around human habitation (Mukhopadhyay and Mazumdar 2017; Panda et al. 2021). Residential habitats provide abundant food sources for omnivores, such as insects and fruits. In addition, other food sources can be found in residential areas, such as grains, food scraps, and other invertebrates. Due to the ability to obtain food from a wide variety of sources, omnivores are capable of exploiting human habitation (Mukhopadhyay and Mazumdar 2019). In addition, omnivorous species such as *P. goiavier* are generalists and commonly found around humans and show tolerance to open areas such as residential habitats (Eaton et al. 2021).

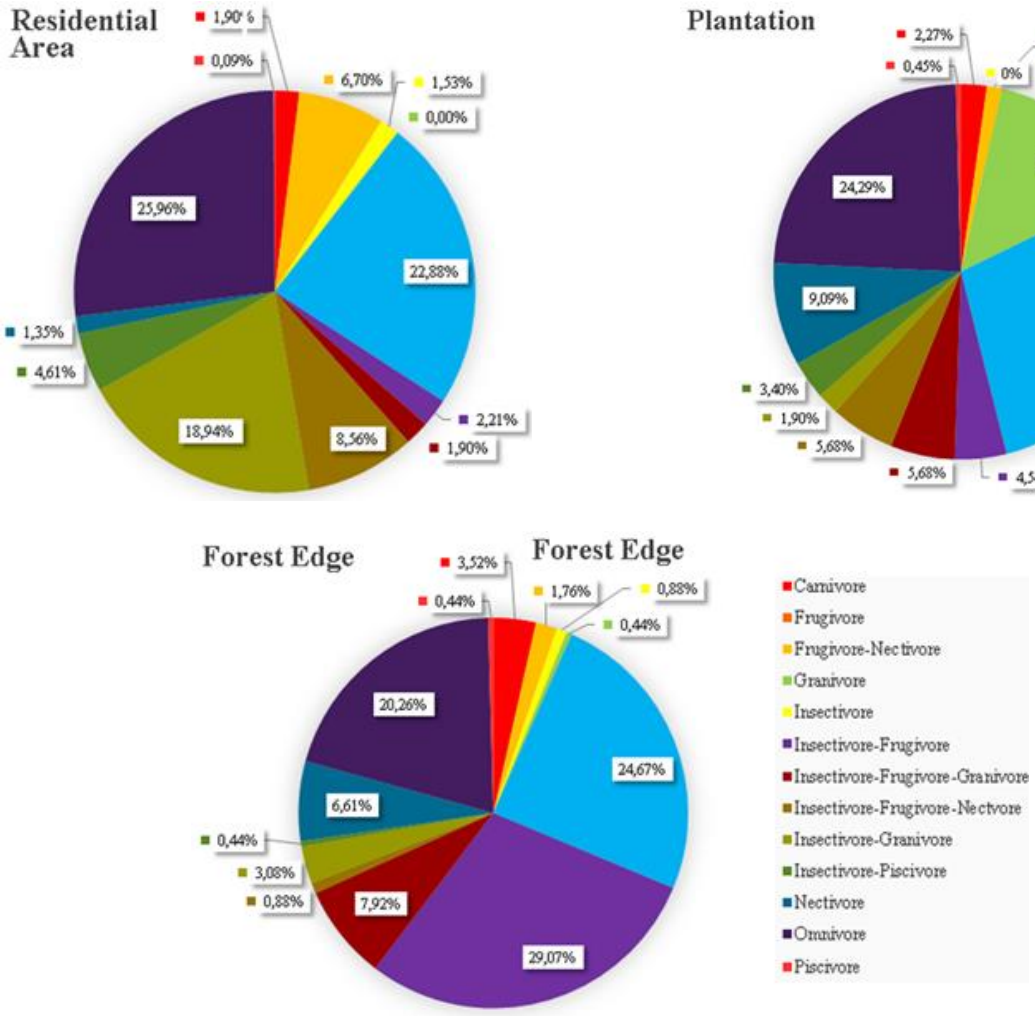

Figure 5. Percentage abundance of bird feeding guilds found in different habitats. Residential areas had omnivores as the most abundant feeding guild found. Plantation had insectivores as the most abundant feeding guild, while forest edge had insectivore-frugivore as the most abundant feeding guild

Insectivores are the second most common feeding guild found across three habitats. It is expected since insectivores make up the most common guilds in the world, using insects as a source of food (Losey and Vaughan 2006). Even frugivores eat insects to meet their protein needs (Bosque and Pacheco 2000). Insectivores, such as *Hirundo rustica* (Linnaeus, 1758) in residential habitat and *O. ruficeps* in plantation habitat, are abundant in both particular habitats. It is consistent with previous research conducted by Panda et al. (2021) on residential habitats, also Ramlah et al. (2021), and Nursyamin et al. (2023) on plantations. Residential areas and plantations are human-modified habitats, which may have resulted in an insect-rich ecosystem, increasing the diversity of insectivore birds (Tanalgo et al. 2015; Panda et al. 2021; Ramlah et al. 2021).

Insectivore-frugivores are plentiful in the forest edges. The members of this guild, such as *A. panayensis*, use fruits and insects as their diet. *A. panayensis* is also part of mixed-species bird flocks, usually consisting of insectivores. Forest edges are known to support the existence of mixed-species bird flocks (Winarni et al. 2019), explaining the number of insectivorous birds found here. Previous research also suggests that insectivores and frugivores are usually found in forests (Nugroho et al. 2023; Winarni et al. 2023), supporting the high abundance of this guild in forest edges. However, Pandey et al. (2021) suggest that the abundance of frugivores does not necessarily correlate with certain habitat types and is more specific to the fruiting season.

NMDS analysis (Figure 6) illustrates the dissimilarity of species and feeding guilds found in the three habitats. According to the distribution of species, birds in the residential habitat have a more uniform pattern and tend to cluster when compared to the other two habitats. There is also an overlap between bird communities in the residential area and plantation habitats. It shows that there is little difference between bird communities in the two habitats. Meanwhile, bird communities in forest-edge habitats had a wider distribution and did not overlap with those in other habitats. Compared with the NMDS analysis of feeding guilds, while forest edge birds have a wider distribution, their community overlaps with the bird community in the plantation. It shows that these two communities on the forest edge and the plantation are closer to each other. Meanwhile, birds in residential areas tend to cluster closely with each other, showing a more uniform pattern than the other two habitats. Overall, the analysis of both figures shows three different clusters that could be distinguished as three different habitats.

As shown by analysis based on species, birds in the forest edge showed fewer similarities than those in the other two habitats. It is because more species are found in the forest edge (e.g., *B. rhinoceros*, *Chloropsis venusta* (Bonaparte, 1850), and *P. zeylanicus*), and some species are found in neither residential areas nor plantation habitats. These birds usually prefer forest or forest edge habitat (MacKinnon et al. 2010), showing their exclusivity. Meanwhile, residential areas and plantations are more similar due to several granivores in both habitats, such as *Streptopelia chinensis* (Scopoli, 1786) and *Lonchura* spp. According to feeding guilds analysis, forest edge and plantations are more similar due to similar feeding guilds in both habitats: the insectivore-frugivore-granivore guild. One of the species inside the particular guild, *Pycnonotus brunneus* (Blyth, 1845), is abundant in both habitats. The *P. brunneus* is a generalist usually found in early succession areas (Kerdkaew et al. 2014), explaining its abundance in the forest edge. Several fig species are also found along the edge of plantation habitats, explaining the abundance of *P. brunneus* in plantations. Similar results show overlapped communities between forest and mixed farmland/palm plantations, particularly for generalist species (Winarni et al. 2023).

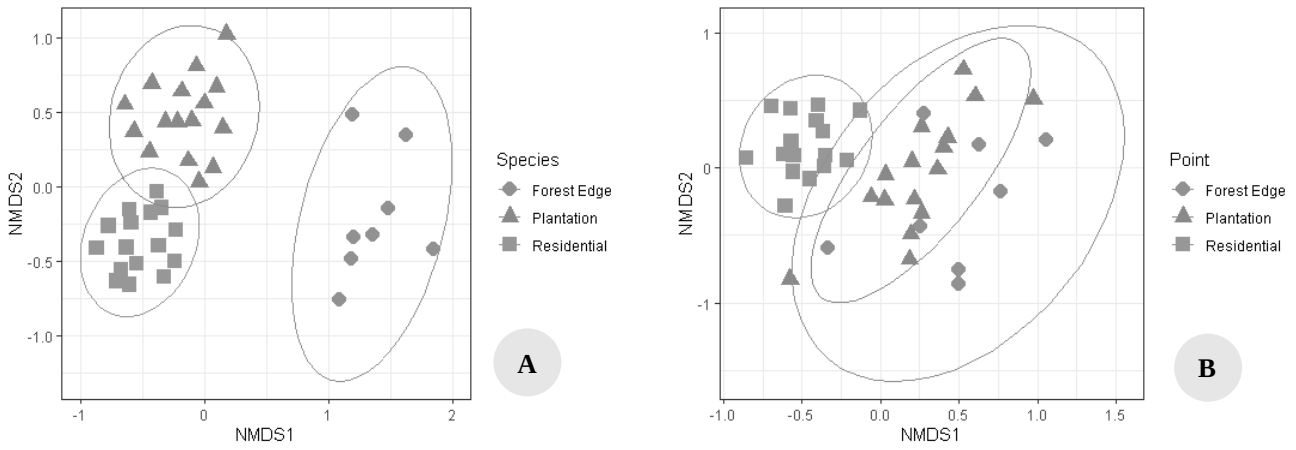

Figure 6. Comparison of NMDS analysis based on species (A) and feeding guilds (B) found in three observed habitats. According to Figure 6.A, the overlapping between residential area and plantation habitats shows that the species composition found in both habitats is more similar. Meanwhile, the overlapping between the forest edge and plantation habitat found in Figure 6.B shows that the feeding guilds are more similar in both habitats

Table 2. Relationship between canopy/understory cover and feeding guilds. Canopy cover correlates negatively to several guilds, while understory cover correlates positively to three guilds

Feeding guild	Canopy cover		Understory cover	
	r	p-value	r	p-value
Carnivore	0.344	0.030	-0.264	0.099
Frugivore	0.107	0.510	0.097	0.552
Frugivore-Nectivore	**-0.491***	0.001	0.291	0.069
Granivore	**-0.533***	0.000	**0.488***	0.001
Insectivore	**-0.434**	0.005	0.318	0.046
Insectivore-Frugivore	0.121	0.458	-0.279	0.081
Insectivore-Frugivore-Granivore	0.334	0.035	-0.093	0.567
Insectivore-Frugivore-Nectvore	**-0.634***	0.000	**0.43***	0.006
Insectivore-Granivore	**-0.614****	0.000	0.36	0.023
Insectivore-Piscivore	**-0.666****	0.000	0.358	0.023
Nectivore	**0.478***	0.002	-0.218	0.177
Omnivore	**-0.686****	0.000	**0.435***	0.005
Piscivore	0.101	0.535	-0.101	0.535

Note: Significant values are marked with bolder fonts and asterisk. A double asterisk means the value is significant at p-value < 0.01, while single asterisk means the value is significant at p-value < 0.05

The relationship between coverage and feeding guilds

Previous research stated that coverage is associated positively with functional guild richness due to improved nesting, foraging, and shelter sites by providing many options for birds (Gebremichael et al. 2022). Our studies show the relationship between canopy coverage and feeding guilds is significant ($p < 0.05$). Canopy coverage correlates negatively with several guilds, e.g. frugivore-nectivores ($R^2 = 0.242$), granivores ($R^2 = 0.284$), insectivores ($R^2 = 0.188$), insectivore-frugivore-nectivores ($R^2 = 0.401$), insectivore-granivores ($R^2 = 0.377$), nectivore ($R^2 = 0.228$), and omnivores ($R^2 = 0.470$). Meanwhile, understory coverage shows a positive correlation for granivores ($R^2 = 0.238$), insectivore-frugivore-nectivores ($R^2 = 0.185$), and omnivores ($R^2 = 0.189$) (Table 2).

We found that canopy coverage shows a negative correlation with several guilds. It may be because large canopy gaps could provide abundant food resources for birds, such as flowers and fruits from fast-growing plants (e.g., *Macaranga* spp., *Melastoma* spp.) (Atikah et al. 2021). Greenberg et al. (2023) also suggested that the removal of overstory can increase the density of understory plants and increase bird species richness, especially those that utilize understory plants. Many species from omnivore and insectivore guilds, such as *P. montanus, P. goiavier, H. rustica,* and *O. ruficeps*, are usually spotted foraging in open-habitat (MacKinnon et al. 2010; Eaton et al. 2021), hence explaining the negative correlation between canopy coverage and some of the guilds. Nevertheless, other studies stated otherwise, as their findings suggested that canopy and understory cover correlates positively with birds (Beskardes 2020; Ajloon et al. 2021; Villaseñor et al. 2021; Gebremichael et al. 2022). Our study shows a positive correlation of understory coverage with some of the guilds, possibly due to the behavior of foraging from bushes and shrubs found in some species (e.g., *Geopelia striata* (Linnaeus, 1766), *S. chinensis*, *Centropus sinensis* (Stephens, 1815)) (MacKinnon et al. 2010). We conclude that the correlation between coverage and feeding guilds may show different results in other locations and may be specific to each location or species.

Conclusion, overall, we found Pycnonotidae to be the largest family in three habitats combined. Forest edges tend to support more diversity and evenness for birds due to their complex vegetation and advanced level of succession. We also found omnivores and insectivores are predominant across habitats due to residential areas, plantation, and forest-edge properties in supporting the thriving lives of particular feeding guilds. NMDS species analysis showed that residential areas and plantations were more similar, but plantations and forest edge habitats were closer to each other when we examined feeding guilds. Canopy and understory coverage correlated with several feeding guilds might occur due to the different foraging behavior in some bird species. The variety of resources and feeding guilds found in various habitats suggested the importance of these habitats and the need to manage them as a landscape for protecting bird diversity.

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REFERENCES

Ajloon FH, Xie D, Junxue S, RuiTing Z, Inyang A. 2021. Impact of vegetation vover structure on birds' community at Tianfu National Wetland Park in Jiangsu Kunshan, China. Res Sq. DOI: 10.21203/rs.3.rs-893247/v1.

Alignier A, Alard D, Chevalier R, Corket E. 2014. Can contrast between forest and adjacent open habitat explain the edge effects on plant diversity? Acta Bot Gallica 161 (3): 253-259. DOI: 10.1080/12538078.2014.902771.

Arriaga-Weiss SL, Calmé S, Kampichler C. 2007. Bird communities in rainforest fragments: Guild responses to habitat variables in Tabasco, Mexico. Biodivers Conserv 17: 173-190. DOI: 10.1007/s10531-007-9238-7.

Atikah SN, Yahya MS, Norhisham AR, Kamarudin N, Sanusi R, Azhar B. 2021. Effects of vegetation structure on avian biodiversity in a selectively logged hill dipterocarp forest. Glob Ecol Conserv 28: e01660. DOI: 10.1016/j.gecco.2021.e01660.

Ayat A, Tata HL. 2015. Diversity of birds across land use and habitat gradients in forests, rubber agroforests and rubber plantations of North Sumatra. Indones J For Res 2 (2): 103-120. DOI: 10.20886/ijfr.2015.2.2.103-120.

Beskardes V. 2020. Habitat selection of insectivorous birds in Western Black Sea Region of Turkey. Appl Ecol Env Res 18 (6): 7551-7562. DOI: 10.15666/aeer/1806_75517562.

Bibby C, Jones M, Mardsen S. 1998. Expedition Field Techniques: Bird Survey. Royal Geographical Society, London.

Bosque C, Pacheco MA. 2000. Dietary nitrogen as a limiting nutrient in frugivorous birds. Revista Chilena de Historia Natural 73: 441-450. DOI: 10.4067/S0716-078X2000000300007.

Dinanti RV, Winarni NL, Supriatna J. 2018. Vertical stratification of bird community in Cikepuh Wildlife Reserve, West Java, Indonesia. Biodiversitas 19 (1): 134-139. DOI: 10.13057/biodiv/d190120.

Eaton JA, van Balen B, Brickle NW, Rheindt FE. 2021. Birds of the Indonesian Archipelago. Greater Sundas and Wallacea. Lynx Edicions, Barcelona.

Gebremichael G, Hundrea K, Decker LD, Aerts R, Lens L, Atickem A. 2022. Bird community composition and functional guilds response to vegetation structure in Southwest Ethiopia. Forests 13 (12): 2068. DOI: 10.3390/f13122068.

Gray MA, Baldauf SL, Mayhew PJ, Hill JK. 2007. The response of avian feeding guilds to tropical forest disturbance. Conserv Biol 21 (1): 133-141. DOI: 10.1111/j.1523-1739.2006.00557.x.

Greenberg CH, Whitehead M, Lanham JD, Tomcho J. 2023. Shelterwood harvests promote high breeding bird diversity and shrubland species for less than 10 years in hardwood forests. For Ecol Manag 545: 121257. DOI: 10.1016/j.foreco.2023.121257.

Hadinoto, Mulyadi A, Siregar YI. 2012. Bird species diversity in Pekanbaru City forest. Jurnal Ilmu Lingkungan 6 (1): 25-42.

Hashim NEN, Mansor MS, Abdullah NA, Ramli R. 2021. The diet of a roosting population of asian glossy starling *Aplonis panayensis* in Jelebu, Negeri Sembilan, Malaysia. Sains Malays 50 (10): 2885-2898. DOI: 10.17576/jsm-2021-5010-04.

Hofmeister J, Hošek J, Babrec M, Kočvara R. 2017. Spatial distribution of bird communities in small forest fragments in central Europe in relation to distance to the forest edge, fragment size and type of forest. For Ecol Manag 401: 255-263. DOI: 10.1016/j.foreco.2017.07.005.

Hsieh TC, Ma KH, Chao A. 2016. iNEXT: An R package for interpolation and extrapolation of species diversity (Hill numbers). Methods Ecol Evol 7 (12): 1451-1456. DOI: 10.1111/2041-210X.12613.

Huang Q, Swatantran A, Dubayah R, Goetz SJ. 2014. The influence of vegetation height heterogeneity on forest and woodland bird species richness across the United States. PLoS ONE 9 (8): e103236. DOI: 10.1371/journal.pone.0103236.

Katuwal HB, Basnet K, Khanal B, Devkota S, Rai SK, Gajurel JP, Scheidegger C, Nobis MP. 2016. Seasonal changes in bird species and feeding guilds along elevational gradients of the Central Himalayas, Nepal. PLOS One 11 (7): e0158362. DOI: 10.1371/journal.pone.0158362.

Kerdkaew T, Gale GA, Bumrungsri S. 2014. Preliminary diet analysis reveals the dispersal of an exotic plant by two native bulbuls in an early successional habitat, Krabi, Southern Thailand. Trop Nat Hist 14 (1): 35-42.

Losey JE, Vaughan M. 2006. The economic value of ecological services provided by insects. Bioscience 56 (4): 311-323. DOI: 10.1641/0006-3568(2006)56[311:TEVOES]2.0.CO;2.

Lubis, MI, Hussein S, Hadi AN, Rumampea EE, Yasin A, Trihangga A, Tarmizi, Marthy W. 2019. Monitoring Forest Cover Change in Gunung Leuser National Park and Surrounding Areas from 2000-2017. Taman Nasional Gunung Leuser & WCS Indonesia Program, Medan. [Indonesian]

MacKinnon J, Pihllips K, van Balen B. 2010. Birds of Sumatra, Java, Bali and Kalimantan. Puslitbang Biologi LIPI, Bogor. [Indonesian]

Magurran AE. 2004. Ecological Diversity and Its Measurement. Blackwell Science Ltd, Oxford.

Matsuba M, Nishijima S, Katoh K. 2016. Effectiveness of corridor vegetation depends on urbanization tolerance of forest birds in central Tokyo, Japan. Urban For Urban Green 18: 173-181. DOI: 10.1016/j.ufug.2016.05.011.

Mohd-Azlan J, Fang VAM, Kaicheen SS, Lok L, Lawes MJ. 2019. The diversity of understorey birds in forest fragments and oil palm plantation, Sarawak, Borneo. J Oil Palm Res 31 (3): 437-447. DOI: 10.21894/jopr.2019.0033.

Moudrý V, Moudrá L, Barták V, Bejček V, Gdulová K, Hendrychová M, Moravec D, Musil P, Rocchini D, Šťastný K, Volf O. 2021. The role of the vegetation structure, primary productivity and senescence derived from airborne LiDAR and hyperspectral data for birds diversity and rarity on a restored site. Landsc Urban Plan 210: 104064. DOI: 10.1016/j.landurbplan.2021.104064.

Mukhopadhyay S, Mazumdar S. 2017. Composition, diversity and foraging guilds of avifauna in a suburban area of Southern West Bengal, India. The Ring 39 (1): 103-120. DOI: 10.1515/ring-2017-0004.

Mukhopadhyay S, Mazumdar S. 2019. Habitat-wise composition and foraging guilds of avian community in a suburban landscape of lower Gangetic plains, West Bengal, India. Biologia 74: 1001-1010. DOI: 10.2478/s11756-019-00226-x.

Nasution J, Masitah PD, Riyanto. 2016. Ethnobotanical studies of medicinal plants by ethnic communities in the hamlet of Aras Napal Kiri and Hamlet of Aras Napal Kanan Bukit Mas Village Besitang Sub-district Langkat District. Jurnal Biosains 2 (2): 91-96. DOI: 10.24114/jbio.v2i2.4225. [Indonesian]

Nugroho SPA, Mardiastuti A, Mulyani YA, Rahman DA. 2023. Bird communities in the tropical peri-urban landscape of Bogor, Indonesia. Biodiversitas 24 (12): 6988-7000. DOI: 10.13057/biodiv/d241260.

Nursyamin Z, Yahya MS, Atikah SN, Tohiran KA, Norhisham AR, Othman NW, Lechner AM, Azhar B. 2023. Identifying indicator bird species for sustainable oil palm plantation certification. J Clean Prod 415: 137852. DOI: 10.1016/j.jclepro.2023.137852.

O'Connell TJ, Jackson LE, Brooks RP. 2000. Bird guilds as indicators of ecological conditions in the Central Appalachians. Ecol Appl 10 (6): 17061721. DOI: 10.2307/2641233.

Oksanen J, Blanchet FG, Kindt R, Legendre P, Minchin P, O'Hara RB, Simpson G, Solymos P, Stevens MHH, Wagner H. 2015. Vegan: Community Ecology Package. R Package Vegan, Vers. 2.2-1. World Agroforestry.

Ouin A, Cabanettes A, Andrieu E, Deconchat M, Roume A, Vigan M, Larrieu L. 2015. Comparison of tree microhabitat abundance and diversity in the edges and interior of small temperate woodlands. For Ecol Manag 340: 31-39. DOI: 10.1016/j.foreco.2014.12.009.

Panda BP, Prusty BAK, Panda B, Pardhan A, Parida SP. 2021. Habitat heterogeneity influences avian feeding guild composition in urban landscapes: Evidence from Bhubaneswar, India. Ecol Process 10: 31. DOI: 10.1186/s13717-021-00304-6.

Pandey N, Khanal L, Chapagain N, Singh KD, Bhattarai BP, Chalise MK. 2021. Bird community structure as a function of habitat heterogeneity: A case of Mardi Himal, Central Nepal. Biodiversitas 22 (1): 262-271. DOI: 10.13057/biodiv/d220132.

Ponpithuk Y, Siri S, Safoowong M, Suksavate W, Marod D, Duengkae P. 2020. Temporal variation in the population of bulbuls (Family Pycnonotidae) in lower montane forest, Northern Thailand. Biodiversitas 21 (8): 3644-3649. DOI: 10.13057/biodiv/d210829.

Ramlah S, Santosa Y, Santoso N, Rushayati SB. 2021. The variation of bird diversity in various oil palm land cover in North Mamuju, West Sulawesi, Indonesia. Biodiversitas 22 (7): 3068-3074. DOI: 10.13057/biodiv/d220761.

Remeš V, Harmáčková L, Matysioková B, Runáčová L, Remešová E. 2022. Vegetation complexity and pool size predict species richness of forest birds. Front Ecol Evol 10: 964180. DOI: 10.3389/fevo.2022.964180.

Sadam A, Khan RU, Mahmood S, Gul J. 2021. Spatial distribution and diversity of bird communities in District Mardan, Khyber Pakhtunkhwa, Pakistan. Pakistan J Zool: 1-6. DOI: 10.17582/journal.pjz/20200307110312.

Şekercioğlu CH, Daily GC, Ehrlich PR. 2004. Ecosystem consequences of bird declines. Proc Natl Acad Sci U S A 101 (52): 18042-18047. DOI: 10.1073/pnas.040804910.

Setyono P, Himawan W. 2018. Analyses of bioindicators and physicochemical parameters of water of Lake Tondano, North Sulawesi Province, Indonesia. Biodiversitas 19 (3): 867-874. DOI: 10.13057/biodiv/d190315.

Shafie NJ, Anuar H, David G, Ahmad A, Abdullah MT. 2022. Bird species composition, density and feeding guilds in contrasting lowland dipterocarp forests of Terengganu, Peninsular Malaysia. Trop Ecol 64: 238-248. DOI: 10.1007/s42965-022-00267-5.

Shakya SB, Sheldon FH. 2017. The phylogeny of the world's bulbuls (Pycnonotidae) inferred using a supermatrix approach. Ibis 159 (3): 498-509. DOI: 10.1111/ibi.12464.

Subasinghe K, Sumanapala AP, Weerawardhena SR. 2014. The impact of forest conversion on bird communities in the northern flank of the Knuckles Mountain Forest Range, Sri Lanka. J Asia-Pacific Biodivers 7 (4): 367-371. DOI: 10.1016/j.japb.2014.07.004.

Tanalgo KC, Pineda JAF, Agravante ME, Amerol ZM. 2015. Bird diversity and structure in different land-use types in lowland South-Central Mindanao, Philippines. Trop Life Sci Res 26 (2): 85-103. DOI: 10.5281/zenodo.8187007.

Tu H-M, Fan M-W, Ko JC-J. 2020. Different habitat types affect bird richness and evenness. Sci Rep 10 (1): 1221. DOI: 10.1038/s41598-020-58202-4.

Tworek S. 2007. Factors affecting bird species diversity on a local scale: A case study of a mosaic landscape in southern Poland. Pol J Ecol 55 (4): 771-782.

van Halder I, Barbaro L, Jactel H. 2011. Conserving butterflies in fragmented plantation forests: Are edge and interior habitats equally important? J Insect Conserv 15: 591-601. DOI: 10.1007/s10841-010-9360-9.

Villaseñor NR, Escobar MAH, Hernández HJ. 2021. Can aggregated patterns of urban woody vegetation cover promote greater species diversity, richness and abundance of native birds? Urban For Urban Green 61: 127102. DOI: 10.1016/j.ufug.2021.127102.

Winarni NL, Mitchell SL, Anugra BG, Deere NJ, Yordan K, Immanuel B, Zakaria Z, Gaib MAW, Supriatna J, Struebig MJ. 2023. Bird diversity in the forests and coconut farms of Sulawesi, Indonesia. Oryx: 1-10. DOI: 10.1017/S0030605323000315.

Winarni NL, Nuruliawati N, Afifah Z. 2019. Assessment of surrogate of ecosystem health using indicator species and mixed-species bird flock. Environ Nat Resour 17 (3): 11-18. DOI: 10.32526/ennrj.17.3.2019.18.

Withaningsih S, Parikesit, Alham RF. 2020. Diversity of bird species in the coffee agroforestry landscape: Case study in the Pangalengan Sub-district, Bandung District, West Java, Indonesia. Biodiversitas 21 (6): 2467-2480. DOI: 10.13057/biodiv/d210619.