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# Bird Community Responses to Edge Areas in Sengon (*Paraserianthes falcataria*) Plantation in Kediri, Indonesia

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## ABSTRACT

Habitat edges modify environmental conditions and species interactions; nonetheless, their impact on bird communities in tropical plantation landscapes is still not well comprehended. This study examined bird community responses to edge formation in sengon (*Paraserianthes falcataria*) plantations in Kediri, East Java, Indonesia. Bird surveys were conducted using point counts across sengon interior, agroforestry edge, and pineapple plantation edge. Species diversity was compared using Hutcheson's *t*-test, and feeding guild was analyzed using PERMANOVA. A total of 30 bird species from 20 families and 2,338 individuals were detected. The sengon interior supported the highest species richness (26 species) and diversity (H' = 2.463), compared with 22 species (H' = 2.335) at the agroforestry edge and 22 species (H' = 2.162) at the pineapple edge, though not significantly different ($p > 0.05$). The lowest encounter rates occurred in the interior (75.3 ± 6.9 individuals/hour), and higher rates occurred at the agroforestry edge (81.2 ± 9.5) and the pineapple edge (79.7 ± 7.4). Feeding guild differed among habitats (PERMANOVA, $p = 0.003$), although pairwise comparisons were not statistically significant ($p = 0.100$–$0.106$). Arboreal insectivores prevailed at the agroforestry edge (22.7%), aerial insectivores at the pineapple edge (18.2%), and both guilds were equally dominant in the interior (19.2%). These results indicate that sengon plantation areas maintain ecological importance for supporting both taxonomic and functional aspects of bird diversity in agricultural environments. Preserving habitat quality and supplementary habitat resources in neighboring areas might further strengthen the ecological function of sengon plantation patches in bird conservation.

## Introduction

Habitat edges define the boundary between two neighboring habitats that vary in structure and environment, serving as zones for dynamic interactions among biological communities [1]. Edge effects involve alterations in species composition, population density, and ecological processes that take place near these borders [2]. Depending on the differences between neighboring habitats and the characteristics of the species present, these impacts can either elevate or diminish biodiversity [3,4]. Birds serve as effective indicators due to their trophic diversity, considerable mobility, and heightened sensitivity to changes in habitat [5]. Nonetheless, their reactions may vary by ecological category. Generalist species frequently thrive at habitat boundaries, whereas specialist species usually diminish as habitat alterations escalate [6–8].

Alongside changes in species richness, edge effects can restructure bird communities by shifting the relative prevalence of feeding guilds and the equilibrium between generalist and specialist species. These changes in feeding guilds can indicate trophic interactions and overall ecosystem resilience [9]. A functional perspective

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can enhance biodiversity assessments and provide greater insight into the ecological processes that take place at habitat edges.

Plantation forests generally exhibit reduced biodiversity compared to natural forests, a phenomenon attributed to their uniform structure and distinct edges, which hinder species movement [10–12]. The high contrast at these edges enhances variations in microclimate and plant diversity, thereby intensifying edge effects [13]. Nevertheless, fragmentation may occasionally enhance landscape-level diversity by increasing the overall edge length and fostering habitat variability [14–17]. This indicates that plantation forest mosaics can continue to aid biodiversity conservation if their boundaries are effectively managed. Nonetheless, avian reactions to these boundaries frequently rely not just on the immediate plant structure but also on the overall landscape makeup and arrangement. Resource availability, habitat connectivity, and bird movement in agricultural mosaics are affected by interlinked patches like agroforests, monoculture plantations, grasslands, and mixed vegetation, which ultimately influence communities at habitat edges.

Among the cultivated species in Indonesia, sengon (*Paraserianthes falcataria*) is prominent due to its fast growth, adaptability, and economic value [18–20]. Sengon trees are vulnerable to insect pests; nonetheless, they play a vital ecological role by supporting various insect-eating bird communities through their food resources [21,22]. Although numerous studies have reported birds using sengon trees for feeding, perching, or nesting [23–25], none have specifically investigated the impact of edge formation on the bird community composition in sengon plantations. Studying this gap is crucial because sengon plantations usually exist in diverse agricultural landscapes and frequently adjoin various land uses, creating edge habitats that differ in their structure and resource access.

This study was carried out in a sengon plantation patch surrounded by various agricultural environments to assess how bird communities react to different edge contexts within a managed tropical landscape. Specifically, this study aimed to (1) compare bird community composition between interior and edge habitats of sengon plantations with different edge types, and (2) analyze the variation in avian feeding guilds across these habitats to assess edge-related functional shifts in managed tropical landscapes.

## Materials and Methods

### Study Area

The study was conducted from May to July 2024 in a sengon plantation managed by the Kediri Forest Management Unit, locally known as Kesatuan Pemangkuan Hutan (KPH) Kediri. Administratively, the study site was in Gadungan Village, Puncu Sub-district, Kediri Regency, East Java, Indonesia (Figure 1), at an elevation of 200-400 m above sea level. Specifically, the study was conducted in the Jatirejo Forest Section (RPH Jatirejo) and Pare Forest Subdistrict (BKPH Pare) within the KPH Kediri management area.

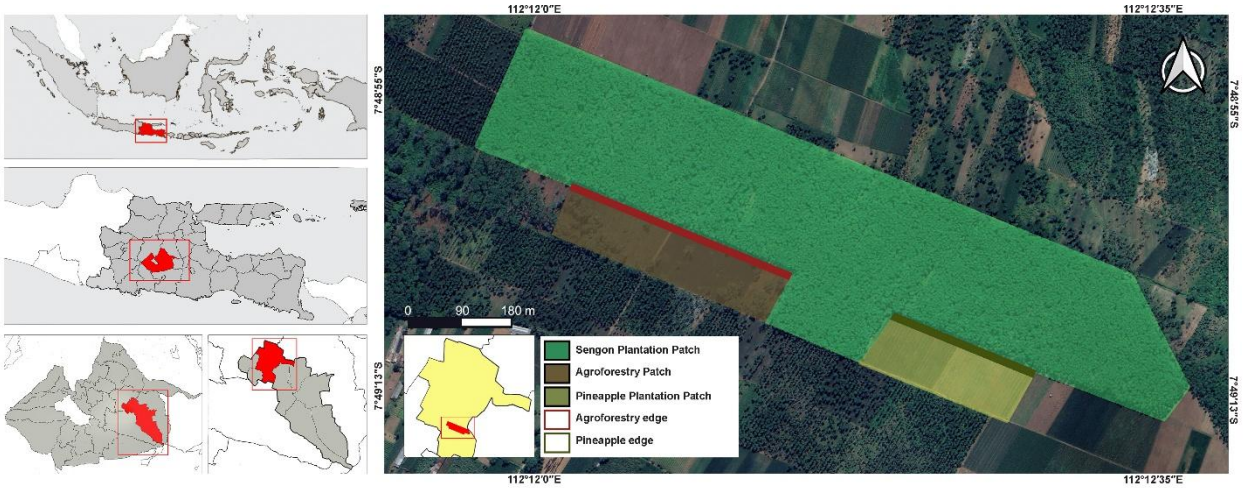


**Figure 1.** The study site is located within a sengon (*Paraserianthes falcataria*) plantation in Gadungan Village, Puncu District, Kediri Regency, East Java, Indonesia. The map shows the sengon plantation patch bordering an agroforestry patch and a pineapple plantation patch.

The study was carried out in patch 9A (7°49'00.50"S, 112°11'55.90"E – 7°49'06.50"S, 112°12'38.80"E), a 5-year-old sengon stand covering 26.5 ha, bordered by 23 adjacent habitat patches representing multiple land cover types (Table 1). Among these, pineapple (*Ananas comosus*) plantations are the most common land use surrounding the study site, cultivated in both monoculture and agroforestry systems. The edge habitats selected for this study were those with the longest edge lengths, namely the pineapple–sengon agroforestry edge (434 m), hereafter referred to as the agroforestry edge, and the pineapple plantation edge (268 m).

**Table 1.** Adjacent habitat patches surrounding sengon plantation patch 9A and their corresponding land-cover types, edge lengths, and areas. Pineapple (*Ananas comosus*) plantations, cultivated as both monocultures and agroforestry systems, represent the most extensive land-cover type bordering the study patch, and the pineapple–sengon agroforestry edge (434 m) and pineapple plantation edge (268 m) were selected as the sampling edges for this study based on their edge length.

| No. | Land-cover type | Edge Length (m) | Area (ha) |
|---|---|---|---|
| 1 | Post-harvest pineapple field | 90 | 0.4 |
| 2 | Bare land | 218 | 1.9 |
| 3 | Maize–balsa agroforestry | 95 | 1.0 |
| 4 | Grassland | 75 | 0.2 |
| 5 | Maize–balsa agroforestry | 88 | 0.2 |
| 6 | Grassland | 76 | 0.2 |
| 7 | Balsa plantation | 52 | 0.2 |
| 8 | Post-harvest maize field | 35 | 0.4 |
| 9 | Maize–balsa agroforestry | 62 | 0.6 |
| 10 | Maize field | 16 | 0.2 |
| 11 | Balsa plantation | 68 | 0.7 |
| 12 | Maize field | 30 | 0.3 |
| 13 | Balsa plantation | 92 | 1.0 |
| 14 | Pineapple plantation | 113 | 0.6 |
| 15 | Mixed garden | 231 | 12.6 |
| 16 | Bare land | 74 | 2.2 |
| 17 | Partially harvested sengon stand | 168 | 4.3 |
| 18 | Pineapple–sengon agroforestry | 434 | 4.4 |
| 19 | Pineapple–balsa agroforestry | 175 | 21.1 |
| 20 | Pineapple plantation | 268 | 2.7 |
| 21 | Chili field | 27 | 0.3 |
| 22 | Pineapple plantation | 192 | 1.9 |
| 23 | Pineapple–balsa agroforestry | 195 | 4.5 |

**Data Collection**

The point-count method was utilized to collect the data [26]. Point counts were established for each habitat type. The total stations were decided based on the accessible length and spatial arrangement of each habitat, ensuring a fixed-radius sampling approach and minimizing overlap among point-count areas. Consequently, 10 points were set up in the sengon interior, 6 points at the agroforestry boundary, and 4 points along the pineapple plantation boundary. Point count stations were positioned at least 100 m apart in the sengon interior, 67 m in the agroforestry edge, and 64 m in the pineapple plantation edge to prevent overlap between sampling regions. Every point count had a set radius of 25 m and lasted for 10 minutes. Edge sampling points were located precisely on the plantation boundary, allowing each 25 m detection radius to extend 25 m into the sengon stand and 25 m into the neighboring habitat (either pineapple plantation or agroforestry), thereby encompassing the interface zone on both sides of the boundary. Interior habitats were designated as areas located at least 105 m from any plantation border to minimize edge effects.

Observations were carried out in the morning (06:30-08:30 AM), midday (11:00 AM-01:00 PM), and afternoon (03:30-05:30 PM), all according to local time (UTC+7), with three repetitions for each period. Bird abundance was represented as individuals per hour, calculated from the overall number of individuals noted divided by the total survey time in each habitat. Data from repeated surveys were combined to calculate habitat-level metrics, including species richness, Shannon diversity, encounter rate (individuals per hour), and

feeding guild proportions. For Permutational Multivariate Analysis of Variance (PERMANOVA), feeding guild data from individual survey occasions (three repeated surveys per habitat type) were retained as replicates to evaluate differences in guild composition among habitats.

All surveys were carried out by one observer to guarantee uniformity in the spotting and identification of birds. Birds flying over the survey region without apparent use of the habitat (e.g., perching, foraging, or other habitat-related behaviors) were omitted from the analyses according to [26], thus minimizing the risk of double-counting transient birds. Surveys took place solely in rain-free intervals with clear visibility and light wind conditions. Surveys planned during unfavorable weather were delayed and carried out when suitable weather conditions were present.

Since the structure of vegetation varied between habitat types, the probabilities of detection might not have been the same across the surveys. The current research utilized fixed-radius point counts and excluded distance sampling or occupancy methods to address imperfect detections. Consequently, potential differences in detectability among habitats should be considered when interpreting patterns of bird abundance and community composition.

**Data Analysis**

Differences in bird community structure among habitat types were analyzed using Hutcheson's t-test [27] based on Shannon–Wiener diversity (H') values [28]. Each bird species was classified into feeding guilds according to its primary diet and foraging stratum, following the criteria adapted from [29], as presented in Table 2. Guild composition among habitat types was compared using PERMANOVA with Bray–Curtis distances in PAST software, using 9,999 permutations [30]. The analysis was based on feeding guild data from nine survey occasions (three repeated surveys for each habitat type), which served as units of replication. Pairwise tests were adjusted using the sequential Bonferroni correction [30].

**Table 2.** Classification of bird feeding guilds recorded in the sengon plantation patch and its adjacent edge habitats, adapted from established dietary and foraging-stratum criteria [29]. Each guild reflects a species' primary diet (e.g., insects, fruit, nectar, or seeds) and the vertical stratum in which it forages (arboreal, terrestrial, or aerial), providing the functional groupings used to compare bird communities among habitats in this study.

| No | Guild | Description |
|---|---|---|
| 1 | Arboreal Frugivore-Insectivore (ABFI) | Foraging mainly in the canopy, consuming fruits as primary food while supplementing with insects |
| 2 | Arboreal Insectivore (ABI) | Feeding predominantly on insects in the canopy, often by gleaning from leaves and branches |
| 3 | Arboreal Frugivore-Nectarivore-Insectivore (ABFNI) | Foraging in the canopy with a mixed diet of fruits, nectar, and insects |
| 4 | Arboreal-Terrestrial Frugivore-Nectarivore-Insectivore (ABTFNI) | Foraging both arboreal and terrestrial strata with a mixed diet of fruits, nectar, and insects |
| 5 | Arboreal-Terrestrial Insectivore (ABTI) | Preying on insects in both canopy and ground layers |
| 6 | Arboreal-Terrestrial Insectivore-Carnivore (ABTIC) | Feeding on insects and small vertebrates, foraging across arboreal and terrestrial |
| 7 | Aerial Insectivore (AI) | Catching flying insects in the air, either through hawking from perches or active aerial sallies. |
| 8 | Bark probing Insectivore (BRI) | Probing insects from bark crevices |
| 9 | Terrestrial Granivore (TG) | Feeding mainly on seeds, typically collected from the ground |
| 10 | Terrestrial Insectivore-Carnivore (TIC) | They feed on terrestrial insects and small vertebrates, such as frogs, lizards, and rodents. |
| 11 | Terrestrial Insectivore (TI) | Foraging mainly for insects on the forest floor, leaf litter, or open ground |
| 12 | Terrestrial Insectivore-Granivore (TIG) | Ground-foraging on seeds as primary food while supplementing with insects |

## Results and Discussion

### Results

#### *Bird Community Differences*

In this study, 30 bird species from 20 different families were documented across the three surveyed habitat types (Table 3). Across all surveys, 2,338 individual bird detections were noted, including 1,129 in the sengon interior, 731 in the agroforestry edge, and 478 in the pineapple plantation. Sixteen species (53.3%) occured in all habitats. Most families were represented by 1 or 2 species, except Cuculidae, which had the highest richness (4 species).

In the sengon interior habitat, 26 bird species from 19 families were observed, resulting in a diversity index (H') of 2.463. The Cuculidae family showed the highest species richness, with three species observed. Based on a total of 15 hours spent on cumulative surveys, 1,129 individual detections were noted, resulting in an average encounter rate of 75.3 ± 6.9 individuals per hour. The Small Minivet (*Pericrocotus cinnamomeus*) was the most abundant species, with 14.9 individuals/hour and a dominance value of 19.8%, followed closely by the Cave Swiftlet (*Collocalia linchi*) at 14.5 individuals/hour and 19.2% of dominance. Certain species, including the Sunda Coucal (*Centropus nigrorufus*), Pacific Swallow (*Hirundo javanica*), and Yellow-vented Bulbul (*Pycnonotus goiavier*), were noted only once during the survey period.

Observations at the agroforestry edge identified 22 bird species from 18 families, resulting in a diversity index (H') of 2.335. Species richness across families was relatively even, with no family contributing to more than two species. Based on a cumulative survey effort of 9 hours across all survey occasions, 731 individual detections were recorded, corresponding to an average encounter rate of 81.2 ± 9.5 individuals per hour was recorded. The Small Minivet also dominated this habitat, accounting for 25.6% of the total abundance, with 20.8 individuals/hour. The plaintive Cuckoo (*Cacomantis merulinus*), Lesser Coucal (*Centropus bengalensis*), and Coppersmith Barbet (*Psilopogon haemacephalus*) were detected only once.

At the pineapple plantation edge, 22 species from 17 families were recorded, with a diversity index (H') of 2.162. Through a total survey effort of 6 hours during all survey periods, 478 individual detections were noted, resulting in an average encounter rate of 79.7 ± 7.4 individuals/hour. The Cave Swiftlet was the most dominant species, with 26.7 individuals/hour and 33.5% of the total. Oriental Honey-buzzard (*Pernis ptilorhynchus*), Sunda Coucal (*Centropus nigrorufus*), Javan Kingfisher (*Halcyon cyanoventris*), and Yellow-vented Bulbul (*Pycnonotus goiavier*) were recorded only once.

**Table 3.** Common name, scientific name, encounter rate (individuals/hour), and relative dominance (%) of bird species recorded in the sengon interior, agroforestry edge, and pineapple plantation edge. The Small Minivet (*Pericrocotus cinnamomeus*) and Cave Swiftlet (*Collocalia linchi*) were consistently among the most abundant species, together accounting for a substantial share of detections across all three habitat types.

| Common name* | Scientific name* | Sengon interior | | Agroforestry edge | | Pineapple plantation edge | |
|---|---|---|---|---|---|---|---|
| | | I/h | D (%) | I/h | D (%) | I/h | D (%) |
| Oriental Honey-buzzard | *Pernis ptilorhynchus* | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 |
| Barred Buttonquail | *Turnix suscitator* | 0.8 | 1.1 | 1.1 | 1.4 | 0.8 | 1.1 |
| Spotted Dove | *Spilopelia chinensis* | 0.3 | 0.4 | 0.2 | 0.3 | 0.0 | 0.0 |
| Zebra Dove | *Geopelia striata* | 5.2 | 6.9 | 7.6 | 9.3 | 4.3 | 5.4 |
| Plaintive Cuckoo | *Cacomantis merulinus* | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 |
| Banded Bay Cuckoo | *Cacomantis sonneratii* | 0.1 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| Lesser Coucal | *Centropus bengalensis* | 0.3 | 0.4 | 0.1 | 0.1 | 0.5 | 0.6 |
| Sunda Coucal | *Centropus nigrorufus* | 0.1 | 0.1 | 0.0 | 0.0 | 0.2 | 0.2 |
| Cave Swiftlet | *Collocalia linchi* | 14.5 | 19.2 | 16.4 | 20.3 | 26.7 | 33.5 |
| House Swift | *Apus nipalensis* | 0.2 | 0.3 | 0.0 | 0.0 | 0.3 | 0.4 |
| Javan Kingfisher | *Halcyon cyanoventris* | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 |
| Collared Kingfisher | *Todiramphus chloris* | 0.9 | 1.2 | 0.7 | 0.8 | 1.2 | 1.5 |
| Blue-tailed Bee-eater | *Merops philippinus* | 1.5 | 2.0 | 1.7 | 2.1 | 0.5 | 0.6 |
| Coppersmith Barbet | *Psilopogon haemacephalus* | 0.1 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 |

| Common name* | Scientific name* | Sengon interior | | Agroforestry edge | | Pineapple plantation edge | |
|---|---|---|---|---|---|---|---|
| | | I/h | D (%) | I/h | D (%) | I/h | D (%) |
| Freckle-breasted Woodpecker | *Dendrocopos analis* | 3.1 | 4.1 | 1.0 | 1.2 | 2.0 | 2.5 |
| Pacific Swallow | *Hirundo javanica* | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| Black-winged Flycatcher-shrike | *Hemipus hirundinaceus* | 1.0 | 1.3 | 0.2 | 0.3 | 0.0 | 0.0 |
| Pied Triller | *Lalage nigra* | 2.7 | 3.6 | 3.0 | 3.7 | 4.0 | 5.0 |
| Small Minivet | *Pericrocotus cinnamomeus* | 14.9 | 19.8 | 20.8 | 25.6 | 13.0 | 16.3 |
| Common Iora | *Aegithina tiphia* | 9.1 | 12.1 | 3.2 | 4.0 | 5.3 | 6.7 |
| Sooty-headed Bulbul | *Pycnonotus aurigaster* | 8.0 | 10.6 | 7.9 | 9.7 | 11.3 | 14.2 |
| Yellow-vented Bulbul | *Pycnonotus goiavier* | 0.1 | 0.1 | 0.0 | 0.0 | 0.2 | 0.2 |
| Golden-bellied Gerygone | *Gerygone sulphurea* | 3.8 | 5.1 | 1.8 | 2.2 | 0.5 | 0.6 |
| Common Tailorbird | *Orthotomus sutorius* | 1.7 | 2.3 | 0.0 | 0.0 | 0.3 | 0.4 |
| Plain Prinia | *Prinia inornata* | 0.5 | 0.7 | 0.7 | 0.8 | 0.7 | 0.8 |
| White-breasted Woodswallow | *Artamus leucorynchus* | 3.1 | 4.2 | 6.1 | 7.5 | 1.0 | 1.3 |
| Ornate Sunbird | *Cinnyris ornatus* | 2.6 | 3.5 | 2.4 | 3.0 | 5.3 | 6.7 |
| Scarlet-headed Flowerpecker | *Dicaeum trochileum* | 0.3 | 0.4 | 1.8 | 2.2 | 0.0 | 0.0 |
| Java Sparrow | *Padda oryzivora* | 0.0 | 0.0 | 0.2 | 0.3 | 0.0 | 0.0 |
| Scaly-breasted Munia | *Lonchura punctulata* | 0.2 | 0.3 | 4.1 | 5.1 | 1.2 | 1.5 |

Note: *: Common names, scientific names, and taxonomic sequence of bird species follow [31]; I/h: Individuals/hour; D: Dominance

The sengon interior had the highest species diversity (H') and species richness, while both edge habitats had fewer species. In contrast, the average number of individuals per observation hour was lowest in the sengon interior, while the agroforestry edge showed the highest abundance, followed by the pineapple plantation. The *t-test results* indicated no significant differences in species diversity (H') among the three habitat types. The *t*-values for the comparisons between the sengon interior and the agroforestry edge ($t$ = 0.7554; $df$ = 155.82), sengon interior and pineapple plantation edge ($t$ = 1.6751; $df$ = 154.52), and agroforestry edge and pineapple plantation edge ($t$ = 0.9723; $df$ = 158.72) were all lower than the critical *t*-value (1.98). For all habitat pairs, $|t| < t$-table ($p > 0.05$), indicating that species diversity did not differ significantly between habitats.

***Feeding Guilds Composition***

Arboreal Insectivores (ABI) dominated the agroforestry edge (22.7%), whereas Aerial Insectivores (AI) were most abundant at the pineapple edge (18.2%) (Table 4). In the sengon interior, both guilds were equally dominant (19.2%). Terrestrial Granivores (TG) were consistently present, with higher proportions in the agroforestry edge (18.2%) and sengon interior (11.5%) than in the pineapple edge (9.1%). Arboreal–Terrestrial Insectivores (ABTI) and Terrestrial Insectivore–Carnivores (TIC) each accounted for 7.7% in the sengon interior and 9.1% in the pineapple edge but were lower in the agroforestry edge (4.6%). Arboreal–Terrestrial Insectivore–Carnivores (ABTIC) and Arboreal–Terrestrial Frugivore–Nectarivore–Insectivores (ABTFNI) peaked at the pineapple edge (13.6% and 9.1%, respectively). Frugivore-related guilds (ABFI and ABFNI) were generally rare (<8%), as were Bark-probing Insectivores (BRI) and Terrestrial Insectivores (TI), both contributing less than 5% across habitats.

**Table 4.** Relative composition (%) of bird feeding guilds recorded in the sengon interior, agroforestry edge, and pineapple plantation edge. Arboreal Insectivores were most dominant at the agroforestry edge, Aerial Insectivores prevailed at the pineapple edge, and both guilds contributed equally in the sengon interior.

| Guild | Sengon Interior | Agroforestry Edge | Pineapple Plantation Edge |
|---|---|---|---|
| *Arboreal Frugivore-Insectivore* (ABFI) | 3.9 | 4.6 | 0.0 |
| *Arboreal Insectivore* (ABI) | 19.2 | 22.7 | 13.6 |
| *Arboreal Frugivore-Nectarivore-Insectivore* (ABFNI) | 7.7 | 9.1 | 4.6 |

| Guild | Sengon Interior | Agroforestry Edge | Pineapple Plantation Edge |
|---|---|---|---|
| *Arboreal-Terrestrial Frugivore-Nectarivore-Insectivore* (ABTFNI) | 7.7 | 4.6 | 9.1 |
| *Arboreal-Terrestrial Insectivore* (ABTI) | 7.7 | 4.6 | 9.1 |
| *Arboreal-Terrestrial Insectivore-Carnivore* (ABTIC) | 3.9 | 4.6 | 13.6 |
| *Aerial Insectivore* (AI) | 19.2 | 13.6 | 18.2 |
| *Bark probing Insectivore* (BRI) | 3.9 | 4.6 | 4.6 |
| *Terrestrial Granivore* (TG) | 11.5 | 18.2 | 9.1 |
| *Terrestrial Insectivore-Carnivore* (TIC) | 7.7 | 4.6 | 9.1 |
| *Terrestrial Insectivore* (TI) | 3.9 | 4.6 | 4.6 |
| *Terrestrial Insectivore-Granivore* (TIG) | 3.9 | 4.6 | 4.6 |

PERMANOVA results indicated an overall difference in the bird feeding guild composition among habitats ($p = 0.003$; $R^2 = 0.524$). However, pairwise comparisons revealed no significant differences between any of the habitat pairs. The p-values were 0.101 for the sengon interior–agroforestry edge, 0.106 for the sengon interior–pineapple plantation edge, and 0.100 for the agroforestry–pineapple plantation edges. These results suggest that variations in feeding guild composition occurred at the community level, but differences between individual habitat pairs were relatively subtle.

## Discussion

The sengon interior supported the highest bird species richness and diversity (H'). This result contradicts the traditional edge-effect hypothesis, which suggests that diversity rises at habitat borders because of the interchange of species from neighboring habitats. Nonetheless, this aligns with recent research indicating that forest interiors frequently maintain greater species diversity than edges, especially in areas with low edge contrast and similar habitat conditions across borders [32]. The lack of significant differences in H' among habitats suggests that structural or compositional contrasts may not have been sufficiently strong to reshape bird communities, resulting in relatively similar overall diversity levels.

The least difference in diversity was noted between the sengon interior and the agroforestry edge among habitats. This pattern probably indicates the comparatively similar vegetation forms and resource distributions common to these habitats. Agroforestry systems can mimic forest environments and benefit numerous forest-dependent species when the complexity of vegetation is elevated [33]. In comparison, the edge of the pineapple plantation showed a more significant decrease in species richness and diversity than the interior. In contrast to agroforestry systems, monoculture pineapple farms offer fewer layers of vegetation and reduced structural complexity, potentially lowering habitat suitability for certain forest-dependent species while benefiting those adapted to open environments [34].

Although the diversity indices showed no significant differences across habitats, this pattern has important ecological implications. The lack of statistically significant differences indicates that the structural variation between sengon interiors and edge habitats is fairly minor, restricting the extent of community turnover usually linked to edge effects. These situations can occur when the types of vegetation, canopy density, and microclimatic variations are quite similar, enabling species to effectively use various habitats. Moreover, numerous generalist and insect-eating species can endure in structurally simplified environments, thus diminishing the overall divergence in diversity metrics between habitats.

Despite these patterns, increased vegetation heterogeneity in edge habitats did not result in greater functional diversity, potentially linked to variations in resource availability across the habitats. The greater bird diversity found in the sengon interior could be linked to a broader array of foraging and nesting options, in addition to habitat conditions that are noted to vary between forest interiors and edges [35–37]. Moreover, a thicker canopy in the interior could lower the likelihood of nest predation in contrast to habitats near the edge [38].

The sengon interior had the lowest encounter rate, possibly reflecting the lower total abundance of dominant generalists despite being the richest in species. In contrast, edge habitats supported greater abundance but were primarily dominated by a limited number of opportunistic species. One species observed was the cave swiftlet (*Collocalia linchi*), constituting one-third of all sightings at the edge of the pineapple plantation. This dominance demonstrates how simplified settings can benefit generalists, despite a decrease in overall species richness [39].

The composition of feeding guilds offers an ecological viewpoint on how habitat features and vegetation structure affect bird communities. This study found that PERMANOVA revealed notable overall differences

in guild composition across habitat types, even though the pairwise comparisons were not significant. This pattern indicates that minor yet steady changes in guild proportions together led to total dissimilarity, even when significant differences weren't evident between specific habitat pairs. These outcomes can occur when there are subtle ecological gradients or when the sample size and test power are restricted [40–42].

Predominantly arboreal (ABI) and aerial (AI) foragers, insectivores dominate all habitats, highlighting the abundance of insect prey in sengon-based systems [21,22]. The dominance of ABI at the agroforestry edge and AI at the pineapple edge suggests guild-specific exploitation of canopy and open-air resources, respectively, whereas the balanced composition in sengon interiors reflects a more structurally complex habitat that supports both. The occurrence of sub-guilds, such as bark-probing and terrestrial insectivores, further illustrates fine-scale niche partitioning among insectivorous species.

Mixed frugivore–insectivore guilds were notably present, especially at the agroforestry border, highlighting the role of extra plant components, like mistletoes (*Scurrula* sp.), which offer fruit resources [43]. The Scarlet-headed Flowerpecker (*Dicaeum trochileum*) and the Coppersmith Barbet (*Psilopogon haemacephalus*) illustrate how frugivores depend on parasitic plants and soft-wooded trees, like sengon, for their feeding and nesting needs [44,45]. Likewise, the exclusively granivorous group (Terrestrial Granivore, TG) attained its greatest percentage at this edge, potentially linked to the availability of seeds from sengon trees and underbrush [24], though birds were not seen directly using sengon seeds during the research. In comparison, the pineapple edge favored a greater number of carnivorous guilds, possibly indicating variations in prey availability and habitat openness [46].

The lack of pure nectarivores in various habitats highlights the constraints of flowering plants as natural nectar providers [47]. This pattern indicates that nectar resources were not as abundant as other food sources in the study area. Insectivorous groups predominated in every habitat type, indicating the common presence of insect prey. Collectively, these results suggest that minor differences in vegetation structure and resource distribution influence guild composition, highlighting the ecological importance of edge and interior habitats for sustaining functional diversity in sengon plantation landscapes.

From a management perspective, these findings highlight that sengon plantations retain ecological functions that support diverse insectivorous and mixed-feeding guilds, even within agricultural matrices. The relatively small taxonomic differences across habitats indicate that these habitats share broadly similar structural and resource conditions, which allow many species to occur across the interior and edge habitats. Despite the variation in guild composition across habitats, the lack of notable pairwise differences indicates that functional variation was fairly limited. Consequently, regulating edges to preserve and enhance overall habitat quality and vegetation structure, alongside bolstering complementary resource features between sengon plantations and nearby habitats, could enhance the role of sengon plantation patches in supporting both taxonomic and functional aspects of avian biodiversity within the surrounding agricultural landscape. These management implications need to be viewed carefully due to the study's restricted spatial coverage and the lack of a clear adjustment for imperfect detection.

## Conclusions

This study shows that bird communities in sengon plantation patches embedded within agricultural landscapes exhibit limited taxonomic differentiation between interior and edge habitats, indicating that broadly similar structural and resource conditions allow many species to occupy multiple habitat types within the agricultural landscape. In contrast, the overall variation in feeding guild composition across the sengon interior, agroforestry edge, and pineapple plantation edge suggests that subtle differences in habitat characteristics may influence habitat use within these managed environments. These patterns underscore the importance of evaluating both taxonomic and functional dimensions when assessing the ecological role of plantation patches and suggest that maintaining habitat quality and enhancing complementary resource characteristics across adjacent habitats can strengthen the contribution of sengon plantation patches to avian diversity conservation in agricultural landscapes. Nevertheless, these results need to be understood considering several limitations, such as unequal sampling efforts across habitat types, the absence of clear detectability adjustments, and the unavailability of direct measurements for food resources and other ecological factors that could affect the bird community composition.

## Author Contributions

**HAM**: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Writing - Original Draft; **AM**: Conceptualization, Methodology, Supervision, Writing - Review & Editing; **YAM**: Conceptualization, Methodology, Supervision, Writing -Review & Editing.

## AI Writing Statement

During the preparation of this work, the authors used ChatGPT and Grammarly to assist in translating text and checking grammar accuracy. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

## Conflicts of interest

There are no conflicts to declare.


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## References


1. Parkins, K.; York, A.; Di Stefano, J. Edge Effects in Fire-Prone Landscapes: Ecological Importance and Implications for Fauna. *Ecology and Evolution* **2018**, *8*, 5937-5948, doi:10.1002/ece3.4076.
2. Ries, L.; Murphy, S.M.; Wimp, G.M.; Fletcher Jr, R.J. Closing Persistent Gaps in Knowledge about Edge Ecology. *Curr. Landsc. Ecol. Rep.* **2017**, *2*, 30-41, doi:10.1007/s40823-017-0022-4.
3. Pfeifer, M.; Lefebvre, V.; Peres, C.A.; Banks-Leite, C.; Wearn, O.R.; Marsh, C.J.; Butchart, S.H.M.; Arroyo-Rodriguez, V.; Barlow, J.; Cerezo, A.; et al. Creation of Forest Edges has a Global Impact on Forest Vertebrates. *Nature* **2017**, *551*, 187–191, doi:10.1038/nature24457.
4. Magura, T.; Lövei, G.L.; Tóthmérész, B. Edge Responses are Different in Edges Under Natural Versus Anthropogenic Influence: A Meta-Analysis using Ground Beetles. *Ecol. Evol.* **2017**, *7*, 1009–1017, doi:10.1002/ece3.2722.
5. Fraixedas, S.; Lindén, A.; Piha, M.; Cabeza, M.; Gregory, R.; Lehikoinen, A. A State-of-the-Art Review on Birds as Indicators of Biodiversity: Advances, Challenges, and Future Directions. *Ecol. Indic.* **2020**, *118*, 106728, doi:10.1016/j.ecolind.2020.106728.
6. Karimnejad, M.; Malekian, M.; Pourmanafi, S.; Mobarakeh, Z.M.; Keramati, S.; Ghased, R.; Ahmadi, M. Forest Edge Encroachment by Rural Orchards Shifts Bird Communities in Favor of Understory Birds: Forest Birds as Indicators of Landscape Changes in Agroecosystems. *Ecol. Indic.* **2024**, *167*, 112698, doi:10.1016/j.ecolind.2024.112698.
7. Hasui, É.; Martensen, A.C.; Uezu, A.; Pimentel, R.G.; Ramos, F.N.; Ribeiro, M.C.; Metzger, J.P. Populations Across Bird Species Distribution Ranges Respond Differently to Habitat Loss and Fragmentation: Implications for Conservation Strategies. *Perspect. Ecol. Conserv.* **2024**, *22*, 43–54, doi:10.1016/j.pecon.2023.11.003.
8. Vallejos, L.M.; Prevedello, J.A.; Vecchi, M.B.; Alves, M.A.S. Species Traits and Latitude Mediate Bird Responses to Forest Edges Globally. *Landsc. Ecol.* **2024**, *39*, 53, doi:10.1007/s10980-024-01845-9.
9. Yilangai, R.M.; Abalaka, J.; Nsor, C.A.; Babale, A.; Karau, S.D.; Ivande, S. Effect of Disturbance on Bird Feeding Guilds in a West African Dry Forest. *Afr. J. Ecol.* **2023**, *61*, 461–468, doi:10.1111/aje.13136.
10. Wang, C.; Zhang, W.; Li, X.; Wu, J. A Global Meta-Analysis of the Impacts of Tree Plantations on Biodiversity. *Glob. Ecol. Biogeogr.* **2022**, *31*, 576–587, doi:10.1111/geb.13440.

11. Lemessa, D.; Mewded, B.; Legesse, A.; Atinfau, H.; Alemu, S.; Maryo, M.; Tilahun, H. Do *Eucalyptus* Plantation Forests Support Biodiversity Conservation? *For. Ecol. Manag.* **2022**, *520*, 120492, doi: 10.1016/j.foreco.2022.120492.
12. Ónodi, G.; Botta-Dukát, Z.; Winkler, D.; Rédei, T. Endangered Lowland Oak Forest Steppe Remnants Keep Unique Bird Species Richness in Central Hungary. *J. For. Res.* **2022**, *33*, 343–355, doi:10.1007/s11676-021-01317-9.
13. Santana, L.D.; Prado-Junior, J.A.; Ribeiro, J.H.C.; Ribeiro, M.A.S.; Pereira, K.M.G.; Antunes, K.; Carvalho, F.A.; van den Berg, E. Edge Effects in Forest Patches Surrounded by Native Grassland are also Dependent on Patch Size and Shape. *For. Ecol. Manag.* **2021**, *482*, 118842, doi:10.1016/j.foreco.2020.118842.
14. Fahrig, L.; Arroyo-Rodriguez, V.; Bennett, J.R.; Boucher-Lalonde, V.; Cazetta, E.; Currie, D.J.; Eigenbrod, F.; Ford, A.T.; Harrison, S.P.; Jaeger, J.A.G.; et al. Is Habitat Fragmentation Bad for Biodiversity? *Biol. Conserv.* **2019**, *230*, 179–286, doi:10.1016/j.biocon.2018.12.026.
15. Chetcuti, J.; Kunin, W.E.; Bullock, J.M. Habitat Fragmentation Increases Overall Richness, but not of Habitat-Dependent Species. *Front. Ecol. Evol.* **2020**, *8*, 607619, doi:10.3389/fevo.2020.607619.
16. Rybicki, J.; Abrego, N.; Ovaskainen, O. Habitat Fragmentation and Species Diversity in Competitive Communities. *Ecol. Lett.* **2020**, *23*, 506–517, doi:10.1111/ele.13450.
17. Riva, F.; Fahrig, L. Landscape-scale Habitat Fragmentation is Positively Related to Biodiversity, Despite Patch-Scale Ecosystem Decay. *Ecol. Lett.* **2023**, *26*, 268–277, doi:10.1111/ele.14145.
18. Basuki, A.; Awaludin, A.; Suhendro, B.; Siswosukarto, S. Compression and Tension Creep Behaviour of LVL Sengon (*Paraserianthes falcataria*). *ASEAN Eng. J.* **2021**, *11*, 73–87, doi:10.11113/aej.v11.16668.
19. Nuroniah, H.S.; Tata, H.L.; Mawazin; Martini, E.; Dewi, S. Assessment on the Suitability of Planting Non-Native Peatland Species *Falcataria moluccana* (Miq.) Barneby & Grimes in Rewetted Peatlands. *Sustainability* **2021**, *13*, 7015, doi:10.3390/su13137015.
20. Rahmah, H.; Wijayanto, N.; Wulandari, A.S. The Growth of Sengon (*Paraserianthes falcataria*) and Citronella (*Cymbopogon nardus*) Productivity Performance in Agroforestry System. *Biodiversitas* **2023**, *24*, 3114–3119, doi:10.13057/biodiv/d240503.
21. Setyawan, Y.P.; Hidayat, P.; Triwidodo, H.; Puliafico, K. Keanekaragaman Serangga Fitofag pada Sengon *Falcataria moluccana* (Miq.) Barneby & J.W. Grimes dari Jawa dan Hawaii di Persemaian di Bogor. *J. Ilmu Pertan. Indones.* **2021**, *26*, 490–498, doi:10.18343/jipi.26.4.490.
22. Sutrisno, Y.A.; Triyogo, A.; Suryanto, P. Insect Community in Sengon (*Falcataria moluccana*) Stands Damaged by Stem Borers at Various Altitudes. *Biodiversitas* **2022**, *23*, 3234–3242, doi:10.13057/biodiv/d230651.
23. Ashari, H.; Sulistyadi, E.; Widodo, W. Potensi Fauna Burung sebagai Daya Tarik Wisata Birdwatching di Hutan Taman Nasional Gunung Merapi, Suaka Margasatwa Sermo dan Sekitarnya (Yogyakarta). *Zoo Indones.* **2019**, *28*, 8–20, doi:10.52508/zi.v28i1.3953.
24. Mardiastuti, A. Urban Trees to Attract Wild Birds in a Tropical Urban Residential Complex in Sentul, West Java, Indonesia. *IOP Conf. Ser. Earth Environ. Sci.* **2021**, *918*, 012003, doi:10.1088/1755-1315/918/1/012003.
25. Maulidya, A.L.; Dasumiati, D.; Widodo, W. Keragaman dan Kepadatan Populasi Burung di Kawasan Hijau Cibinong Science Center (CSC) LIPI, Jawa Barat. *Al-Kauniyah: J. Biol.* **2021**, *14*, 325–334, doi:10.15408/kauniyah.v14i2.19942.
26. Bibby, C.; Jones, M.; Marsden, S. Teknik-teknik Ekspedisi Lapangan: Survei Burung; BirdLife International–Indonesia Programme: Bogor, ID, 2000; ISBN 979-95794-3-0.
27. Magurran, A. E. 1988. *Ecological Diversity and Its Measurement.* Croom Helm: London, UK. ISBN: 978-0691084916.
28. Magurran, A. E. 2004. *Measuring Biological Diversity.* Blackwell Publishing: Oxford, UK. ISBN: 978-0632056330.
29. Ghosh, M.; Chongder, I.; Dutta, A.; Saha, G.K.; Banerjee, S. Species Composition and Classification of Guilds in Birds with Respect to Food and Feeding Behavior: Evidences from Suburban Landscape in Hooghly District, West Bengal. *Asian J. Conserv. Biol.* **2022**, *11*, 143–153, doi:10.53562/ajcb.67216.

30. Anderson, M.J. Permutational Multivariate Analysis of Variance (PERMANOVA). *Wiley StatsRef: Stat. Ref. Online* **2017**, 1–15, doi:10.1002/9781118445112.stat07841.
31. AviList Core Team. *AviList: The Global Avian Checklist*, Version 2025; AviList: Online Database, 2025; doi:10.2173/avilist.v2025. Available online: https://www.avilist.org/checklist/v2025/ (accessed on 11 November 2025).
32. Willmer, J.; Püttker, T.; Prevedello, J.A. Global Impacts of Edge Effects on Species Richness. *Biol. Conserv.* **2022**, *272*, 109654, doi:10.1016/j.biocon.2022.109654.
33. Bennett, R.E.; Sillett, T.S.; Rice, R.A.; Marra, P.P. Impact of Cocoa Agricultural Intensification on Bird Diversity and Community Composition. *Conserv. Biol.* **2022**, *36*(1), e13889, doi:10.1111/cobi.13779.
34. Vallejos, L.M.; Prevedello, J.A.; Vecchi, M.B.; Alves, M.A.S. Species Traits and Latitude Mediate Bird Responses to Forest Edges Globally. *Landsc. Ecol.* **2024**, *39*, 53, doi:10.1007/s10980-024-01845-9.
35. Kim, H.; McComb, B.; Frey, S.; Bell, D.; Betts, M. Forest Microclimate and Composition Mediate Long-Term Trends of Breeding Bird Populations. *Glob. Change Biol.* **2022**, *28*, 6180–6193, doi:10.1111/gcb.16353.
36. Lindsey, B.; Bochio, G.; Anjos, L. Bird Species that Occupy River Edge in Continuous Forest Tend to be Less Sensitive to Forest Fragmentation. *Rev. Bras. Ornitol.* **2019**, *27*, 172–186, doi:10.1007/bf03544468.
37. McGinn, K.; Peery, M.; Zulla, C.; Berigan, W.; Wilkinson, Z.; Barry, J.; Keane, J.; Zuckerberg, B. A Climate-Vulnerable Species uses Cooler Forest Microclimates During Heat Waves. *Biol. Conserv.* **2023**, *283*, 110175, doi:10.1016/j.biocon.2023.110132.
38. Holopainen, S.; Selonen, V.; Krüger, H.; Kotanen, J.; Laaksonen, T.; Miettinen, E.; Nurmi, A.; Uushikala, L.; Väänänen, V.M. Forest Habitat Loss and Human Land Use Alter Predation of Artificial Ground Nests. *For. Ecol. Manag.* **2024**, *561*, 121933, doi:10.1016/j.foreco.2024.121858.
39. Li, W.; Zhu, C.; Grass, I.; Vázquez, D.P.; Wang, D.; Zhao, Y.; Zeng, D.; Kang, Y.; Ding, P.; Si, X. Plant–Frugivore Network Simplification Under Habitat Fragmentation Leaves a Small Core of Interacting Generalists. *Commun. Biol.* **2022**, *5*, 380, doi:10.1038/s42003-022-04198-8.
40. Chen, T.; Xu, M.; Tu, J.; Wang, H.; Niu, X. Relationship Between Omnibus and Post-Hoc Tests: An Investigation of Performance of the F test in ANOVA. *Shanghai Arch. Psychiatry* **2018**, *30*, 60–64, doi:10.11919/j.issn.1002-0829.218014.
41. Alekseyenko, A.V. Multivariate Welch t-test on Distances. *Bioinformatics* **2016**, *32*, 3552–3558, doi:10.1093/bioinformatics/btw524.
42. Sauder, D.C.; DeMars, C.E. An Updated Recommendation for Multiple Comparisons. *Adv. Methods Pract. Psychol. Sci.* **2019**, *2*, 26–44, doi:10.1177/2515245918808784.
43. Rahayu, S.; Triyogo, A.; Widyastuti, S.M.; Ardianyah, F. Pests and Diseases on *Falcataria moluccana* Trees in Agroforestry Systems with Pineapple in East Java, Indonesia. *Biodiversitas* **2021**, *22*, 2779–2788, doi:10.13057/biodiv/d220541.
44. Cheke, R.; Mann, C. Scarlet-headed Flowerpecker (*Dicaeum trochileum*), Version 1.0. In *Birds of the World*; del Hoyo, J., Elliott, A., Sargatal, J., Christie, D.A., de Juana, E., Eds.; Cornell Lab of Ornithology: Ithaca, NY, USA, 2020; doi:10.2173/bow.schflo1.01. Available online: https://birdsoftheworld.org/bow/species/schflo1/cur/introduction (accessed on 12 November 2025).
45. Krishnan, A. Coppersmith Barbet (*Psilopogon haemacephalus*), Version 2.0. In *Birds of the World*; Sly, N.D., Ed.; Cornell Lab of Ornithology: Ithaca, NY, USA, 2023; doi:10.2173/bow.copbar1.02. Available online: https://birdsoftheworld.org/bow/species/copbar1/cur/introduction (accessed on 12 November 2025).
46. Kumar, S.; Sohil, A.; Kichloo, M.A.; Sharma, N. Landscape Heterogeneity Affects Diurnal Raptor Communities in a Sub-Tropical Region of Northwestern Himalayas, India. *PLoS ONE* **2022**, *17*, e0266804, doi:10.1371/journal.pone.0246555.
47. Coetzee, A.; Barnard, P.; Pauw, A. Urban Nectarivorous Bird Communities in Cape Town, South Africa, are Structured by Ecological Generalisation and Resource Distribution. *J. Avian Biol.* **2018**, *49*, e01565, doi:10.1111/jav.01526.