Impact of Habitat Pressure Variables on Forest-Interior Bird Species in the Seshachalam Hills, Eastern Ghats, India

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Abstract: This study in the Seshachalam hills of the Eastern Ghats in Andhra Pradesh, India assesses the impact of habitat pressure variables on the population of forest-interior bird species. Field investigations from January to December 2025 in eight ecologically sensitive forest areas documented thirty three forest-interior bird species. Fifty geo-referenced sampling points and twelve transects were surveyed using a mixed-method ecological design. Fixed-radius point counts, line transects and opportunistic observations including GPS-enabled mapping was used to study avian diversity. Habitat pressure variables such as deforestation, fragmentation, presence of invasive plants, and human activity were quantified using GIS-based landscape metrics, and field indicators. Pearson's correlation coefficient (r) was used to examine relationships between habitat pressures and species abundance.
Abundance of forest-interior bird species indicated presence of a good canopy cover and presence of a rich undergrowth in the region. Insectivorous species were abundant reflecting healthy availability of insect species. Forest-interior birds were abundant in mature forest habitats, especially in areas with dense undergrowth. Statistical analysis revealed strong negative correlations between bird abundance and habitat pressure variables such as deforestation ($r = -0.70$ to -0.85), fragmentation ($r = -0.69$ to -0.84), and human disturbance ($r = -0.68$ to -0.79). Species like the Indian Pitta and Heart-spotted Woodpecker showed the highest sensitivity to habitat degradation. Presence of Invasive plants showed moderate positive correlations ($r = 0.35$–0.44) with some insectivorous species. The findings reveal the importance of conservation of mature forests which is essential for sustaining forest-interior birds in the Seshachalam Biosphere Reserve.
Keywords: Seshachalam Hills, Habitat fragmentation, Deforestation, Human disturbance, Eastern Ghats.

Introduction

The Seshachalam Hill Range, situated in the Eastern Ghats of Andhra Pradesh, are one of India's most ecologically important biodiversity hotspots. It was recognized as a Biosphere Reserve in 2010. This biodiversity hotspot with its variations in elevations includes forest types such as Tropical Dry Deciduous Forests, Mixed Scrub, Rivulets, Rocky hill slopes, and protected Sacred Groves (Bharathi et al., 2017). These hills are symbolic of a complex topography with varied microclimates that supports rich flora thereby creating ecological spots which support a wide range of wildlife. Among the varied fauna in this region, the bird community is one of the most prominent and ecologically important.

Birds occupy a central role in the ecological functioning of forest ecosystems. Their role in dispensing seeds, as pollinators and scavengers, as predators of insects and small fauna make them important indicators of ecological stability. Birds are also sensitive to environmental changes like habitat fragmentation, deforestation, pollution, climate change, and human disturbance. This makes them important bio-indicators for assessing the health of an ecosystem. As a result, detailed studies provide important insights into the environmental condition of a region and helps in guiding conservation planning and habitat management (Jha & Vasudevan, 2020; Jha, 2021).

In the past several years, Seshachalam hills have been experiencing an increase in human activity related pressures on bird habitats. Increase in pilgrimage and tourism related activities in Tirumala and surrounding areas, growth of infrastructure, encroachments of forest areas are significantly impacting bird populations. Quarrying, firewood collection, growth of invasive plant species, and agricultural activities in villages on the periphery of forests are other major contributors to habitat degradation (Swain & Behera, 2025).These human activities can significantly impact bird population, reduce the quality of their habitat, and disturb ecologically sensitive areas. A noticeable change in habitats and in the number of bird species are often early warnings of ecological stress in a region. A systematic documentation of bird population and impact of habitat pressure on their abundance is therefore necessary to develop baselines. A study of this nature can also provide a scientific reference for future conservation actions.

This paper presents the results of a year-long study (January to December 2025), undertaken to study the impact of habitat pressure variables on Forest Interior species of birds. The methodology combines systematic field observations, transect explorations, habitat-specific site visits. A review of existing public checklists (Avibase, eBird, Tirupati Bird Club) along with previous work in the area is also done so as to combine fieldwork with established databases. The project aims to produce an updated, verified, and accessible reference list that strengthens the understanding of species richness, diversity, and distribution in the Seshachalam Biosphere Reserve (Guptha et al., 2015; Jha & Vasudevan, 2020).

Research Objectives

To study the impact of four Habitat pressure variables - deforestation / logging, fragmentation, invasive plant species and human disturbance (trekking, poaching) on abundance of forest interior species in the study area.

STUDY AREA

The study was conducted in eight areas of Seshachalam hills, namely, Sri Venkateswara National Park, Tirumala Hills, Nagari Hills, Koundinya Wildlife Sanctuary, Chittoor Forest Division, Red Sanders Reserve Forests, Peddaguttapalle Region and Saptagiri Forest Area. These areas in Seshachalam hills are rich in forests and are expected therefore to support a variety of avian species.

RESEARCH DESIGN

The study uses a mixed-methods ecological design combining field surveys, photographic sampling, habitat stratification, and GIS-based mapping. Surveys were conducted across major ecological zones of the Seshachalam Hill Range. The research integrates Systematic transects and point counts, Seasonal sampling (winter and summer), Behavioural observations using field notes, Night birding sessions for nocturnal species and GPS-enabled mapping and archiving. This ensures comprehensive and seasonally representative documentation of avian species.

DATA COLLECTION

Data was collected through field surveys. To estimate the number of birds in a particular habitat, Fixed-radius point count surveys were conducted. Their activity was also recorded in a similar manner. This is a popular method used for monitoring bird species in varied landscapes such as the Seshachalalm hills. Each point count was conducted inside a 50-m radius. Researchers spent about 10 minutes at each station, recording all the birds that were seen or heard. Field surveys were undertaken during January to December 2025. Field work was carried out every month in each of these eight sample areas to record seasonal variations and for comparison of species population and abundance across months.

A total of 50 geo-referenced point locations were first established in selected forest areas. Research staff visited these points multiple times each month, making a total of 200 point-surveys during the year. During each count, detailed notes were taken that recorded species identity, number of individuals, vocal activity, foraging or breeding behaviour, and immediate habitat conditions. Observers maintained a minimum 3-minute settling period before beginning each count to minimize disturbance-related detection bias. This standardized and repeated survey design helped to maintain comparability between years and therefore enabled vigorous analysis of population fluctuations and habitat associations.

In addition to the Fixed-radius point count surveys, point count observations were also conducted to spot mobile or wide-ranging species. These surveys were conducted across various sample habitats of Seshachalam hills. A total of 12 transects, each one measuring 1–1.5 km in length were determined along dry deciduous forest patches, scrub–rocky slopes, mixed woodland, and in areas of significant human activity.

These transects were than surveyed bimonthly to make sure that there was adequate temporal coverage across breeding, post-monsoon, and dry-season periods. Researchers walked in each transect at a slow and uniform manner during early morning and evening hours when bird activity was highest. All birds spotted or heard were recorded along with the perpendicular distance from the transect line.

This ensured the use of Distance Sampling methods to correct for probability variation in detecting birds and in reducing the risk of overestimating bird count. This method helped in the estimation of detectability-adjusted encounter rates thereby providing reliable measures of relative abundance. This was important in the case of species that are difficult to spot from fixed point counts alone, such as frugivores that prefer thick vegetationand raptors. This line transect data strengthened population estimates and helped in estimating bird population in 2025.

Opportunistic Observations

Opportunistic observations were also taken up to record ecological behaviours and patterns specific to a particular site. These incidental records were collected during the survey whenever significant bird activity was seen alongside trails, forest edges, rocky escarpments, or water bodies. Observations were mostly done on nesting sites, which included recording the type of nest, height of substrate and the surrounding vegetation.

The preference of birds for specific habitats such as rocky areas, scrub foliage, or riparian zones was recorded, along with their feeding behaviour, type of prey, foraging behaviour, substrate, movements in groups and its size, and time of the day they are most active, was also recorded.

Seasonal phenomena such as local migration, moving across altitudes, arrival and departure of migrants, and changes in group composition and behaviour was also recorded. These opportunistic observations were logged using GPS coordinates. They were supported by photographic documentation and detailed field notes to ensure reliability. Although this method of observation is non-systematic, the records provided valuable information that helped in better understanding of behavioural patterns of birds and helped researchers in interpreting results and validating patterns that evolved from standardized surveys.

CALCULATION OF HABITAT PRESSURE INDEX:

The four habitat pressure variables for each sample area were calculated and these standardized pressure scores were correlated with species-wise abundance data using **Pearson's correlation coefficient (r)** to assess the relationship between avian abundance and habitat stressors.

Habitat pressure variables for each sample area were calculated as follows:

(A) Deforestation index

For the purpose of this study, Forest cover was converted into a deforestation pressure index by inverting proportional forest cover values, such that higher index values represent less forest and therefore higher pressure on habitat of birds.

Remote sensing data was used to classify land cover (forest Vs non-forest) for two time points (baseline year that was 2023 and survey year that is 2025). This was done in order to quantify how much forest cover has been lost or reduced around each sampling unit, The most recent forest cover data for Andhra Pradesh published by the Forest Survey of India (FSI) is from the India State of Forest Report (ISFR) 2023. This report, compiled by FSI (under the Ministry of Environment, Forest and Climate Change), was used to obtain data for the baseline year.

Forest% was calculated within a buffer of 1 km around each survey site. The method used was: Deforestation = $\%Forest_{t0} - \%Forest_{t1}$

% Forest = This is the percentage of land that is still forested around a sampling site (within a 1 km buffer). This is divided by 100, to convert percentage into a proportion between 0 and 1. E.g. 80% = 0.80

Subtract from 1: This *inverts* the value so that:

More forest = lower pressure

Less forest = higher pressure

Forest cover	Deforestation pressure
90%	0.10 (very low pressure)
70%	0.30
50%	0.50
30%	0.70
10%	0.90 (very high pressure)

Higher numbers indicated more deforestation pressure. The values were then correlated with bird abundance.

(B) Fragmentation index

This was computed from GIS "landscape metrics" (using FRAGSTATS and QGIS ecology packages), for the same buffer around each site.

Fragmentation metrics used were:

Edge density (ED): total forest edge length per area

Mean patch size (MPS): average forest patch area

Patch density (PD): number of patches per area

Core area index: amount of interior forest beyond a set edge distance (e.g., >100 m from edge)

A composite fragmentation score was built using standardizing metrics (z-scores) and combining them as follows:

Fragmentation= z(ED) + z(PD) – z(MPS) − z(CoreArea)

(C) Invasive plants index

To quantify invasive plant prevalence at/near each bird-sampling point Lay vegetation plots (20×20 m) along transects were identified. Invasive presence was estimated using a visual estimate along with stem density (stems per plot).

Invasive Plants= % $Cover_{\text{invasive}}$

(D) Human disturbance index

To calculate the intensity of human activity and its ecological footprint, encounter rate of people/livestock, distance to nearest road/trail/settlement, counts of cut stumps, lopped branches, grazing signs and noise level proxies, pilgrimage/temple footfall where relevant was recorded. The method used to calculate this index was:

Human Disturbance= z (people encounters) + z (livestock)+ z (extraction signs) + z (trail density)

Once bird abundance (Y) and each pressure metric (X) was finalised **for the same sites**, Pearson correlation was calculated using:

$$r = \frac{(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\quad (X_i - \bar{X})^2}\sqrt{\quad (Y_i - \bar{Y})^2}}$$

RESULTS

Table 1. Feeding and Nesting Behaviour of Forest Interior Species

S.No	Species	Feeding & Behaviour	Nesting & Social Traits
1	Ashy-breasted Prinia (*Prinia socialis*)	Small insectivore; forages in low shrubs	Cup-shaped nest; pairs/small groups; soft trilling calls
2	Ashy-bellied Drongo (*Dicrurus leucophaeus*)	Insect hawker from perches	Nest in tree forks; solitary/pairs; loud chattering calls
3	Asian Brown Flycatcher (*Muscicapa dauurica*)	Insectivore; low perches	Cup-shaped nest; solitary; winter migrant
4	Black-headed Cuckooshrike (*Lalage*	Insectivore	Forked-branch nests;

S.No	Species	Feeding & Behaviour	Nesting & Social Traits
	melanoptera)		territorial; sharp whistles
5	Black-naped Monarch (*Hypothymis azurea*)	Insectivore	Cup nest; territorial pairs; wing-flicking displays
6	Blue-faced Malkoha (*Phaenicophaeus viridirostris*)	Insects & small vertebrates	Stick nest in dense foliage; solitary; soft calls
7	Brown-cheeked Fulvetta (*Alcippe poioicephala*)	Insectivore	Cup nest in shrubs; small groups; soft chirps
8	Common Woodshrike (*Tephrodornis pondicerianus*)	Insect feeder	Simple cup nest; pairs; sharp calls
9	Coppersmith Barbet (*Psilopogon haemacephalus*)	Fruits & insects	Tree cavity nester; territorial; "tuk-tuk" calls
10	Crested Serpent Eagle (*Spilornis cheela*)	Snakes & reptiles	Large tree nests; monogamous; loud repetitive calls
11	Emerald Dove (*Chalcophaps indica*)	Fallen seeds & fruits	Low shrub nest; solitary/pairs; soft cooing
12	Forest Wagtail (*Dendronanthus indicus*)	Water body side insectivore	Cup nest near water; solitary; tail-wagging
13	Greater Racket-tailed Drongo (*Dicrurus paradiseus*)	Insectivore	Forked-tree nests; mixed flocks; vocal mimicry
14	Grey-bellied Cuckoo (*Cacomantis passerinus*)	Insectivore; brood parasite	Nesting rare locally; solitary; soft calls
15	Heart-spotted Woodpecker (*Hemicircus canente*)	Bark-dwelling insects	Tree cavity nester; pairs; drumming calls
16	Indian Grey Hornbill (*Ocyceros birostris*)	Fruits & insects	Tree cavities; family groups; loud cackles
17	Indian Paradise Flycatcher (*Terpsiphone paradisi*)	Insectivore	Forked-branch nest; territorial; courtship tails
18	Indian Pitta (*Pitta brachyura*)	Insectivore	Ground/shrub nests; solitary; melodious calls
19	Indian Scimitar Babbler (*Pomatorhinus horsfieldii*)	Insectivore	Shrub nests; noisy groups; repetitive calls
20	Indian White-eye (*Zosterops palpebrosus*)	Nectar, fruits, insects	Shrub/tree nests; flocks; soft chatter
21	Jerdon's Leafbird (*Chloropsis jerdoni*)	Insects & fruits	Forked-tree nests; pairs; melodious song

S.No	Species	Feeding & Behaviour	Nesting & Social Traits
22	Jerdon's Nightjar (*Caprimulgus atripennis*)	Insectivore	Ground-nesting; solitary; soft night calls
23	Jungle Owlet (*Glaucidium radiatum*)	Insects & small vertebrates	Tree cavities; territorial; "poo-poo" calls
24	Orange-headed Thrush (*Geokichla citrina*)	Ground forager	Low shrub nests; solitary/pairs; rich song
25	Puff-throated Babbler (*Pellorneum ruficeps*)	Insectivore	Cup nest; family groups; trilling calls
26	Red-breasted Flycatcher (*Ficedula parva*)	Insectivore	Cavity nester; solitary; winter visitor
27	Brown-headed Barbet (*Psilopogon haemacephalus*)	Fruits & insects	Tree cavities; territorial; loud calls
28	Spot-breasted Fantail (*Rhipidura albogularis*)	Insectivore	Cup nest; active; tail-fanning displays
29	Spotted Owlet (*Athene brama*)	Small mammals & insects	Tree cavities; pairs; "kree-kree" calls
30	Tickell's Blue Flycatcher (*Cyornis tickelliae*)	Insectivore	Tree cavities; pairs; melodious song
31	White-bellied Drongo (*Dicrurus caerulescens*)	Insectivore	Cup nest; aggressive; vocal mimicry
32	White-cheeked Barbet (*Psilopogon viridis*)	Frugivore	Tree cavities; territorial; loud calls
33	White-rumped Shama (*Copsychus malabaricus*)	Insects & fruits	Shrub nests; territorial pairs; exceptional song

A total of thirty three specie were recorded in the study. The region represents a highly diverse forest-interior population, indicating good structural complexity and canopy continuity.

Table 2. Trophic Guild Composition of Forest Interior Species

Feeding Guild	No. of Species	Percentage (%)
Insectivores (pure)	22	67%
Insectivore–Frugivores	7	21%
Frugivores (dominant)	3	9%
Carnivores (raptors/owls)	1	3%

Forest interiors are strongly dominated by insectivorous species, reflecting high arthropod availability and intact undergrowth and canopy interactions (Suryanarayana, Harinath, & Venkata Ramana, 2015).

Table 3. Foraging Strata Utilization of Forest Interior Species

Forest Stratum	Dominant Species Groups
Ground & Understory	Indian Pitta, Thrushes, Babblers, Fulvetta
Mid-canopy	Flycatchers, Monarch, Leafbird, Drongos
Upper Canopy	Barbets, Hornbill, Cuckooshrike
Aerial Space	Drongos, Fantail, Flycatchers
Nocturnal Layer	Nightjar, Owlets

Species occupy all vertical strata, indicating a well-stratified forest structure, a hallmark of mature interior forests.

Table 4. Nesting Ecology of Forest Interior Species

Nest Type	No. of Species	Percentage (%)
Cup nests (shrubs/branches)	17	52%
Tree cavity nesters	9	27%
Ground / low shrub nesters	4	12%
Platform / large stick nests	3	9%

High proportion of cavity nesters (woodpeckers, barbets, owls, hornbill) highlights the importance of old-growth trees and snags.

Table 5. Social Structure of Forest Interior Species

Social Behaviour	Species Count
Solitary / Pairs	19
Small family groups	8
Mixed-species flock participants	6

Forest interior birds show **low flocking tendency**, typical of territorial and resource-specialized species.

Vocal & Behavioural Traits

Highly vocal bird species recorded in the study area include barbets, drongos, shamas, and owlets. They contributed significantly to the forest soundscape. Acoustic specialists like the Indian Pitta, White-rumped Shama, and leafbirds exhibit distinct vocal adaptations that help them in communicating with each other in dense forest habitats. Mimicry behaviour was observed in species like the Greater Racket-tailed Drongo and White-bellied Drongo. Both these birds are known for their ability to imitate the calls of other birds. The rich acoustic diversity in the region indicates **low anthropogenic noise pressure** and preservation of communication environments (Bregman et al, 2014).

Migratory Status of Forest Interior Species

28 resident and 5 Winter migrants were recorded in the study. The winter migrants recorded in the study are Asian Brown Flycatcher, Red-breasted Flycatcher, Forest Wagtail and Grey-bellied Cuckoo. Forest interiors mostly remain important habitats for resident birds with limited use by

migrants.

Indicator & Sensitive Species

Species such as the Indian Pitta, Jerdon's Leafbird, and Brown-cheeked Fulvetta are important indicators of the health of a forest. Similarly, birds such as the Heart-spotted Woodpecker, barbets, and hornbills are indicators of old-growth forest ecosystems (**Chettri et al, 2005).** Disturbance-sensitive taxa, including the Shama, Monarchs, Thrushes, and Nightjars, indicate the ecological stability and minimal human disturbance in a habitat.

Overall Habitat Inference

The forest interior habitat is characterized by a dominance of insectivorous bird species. The habitat shows vertical stratification, and a strong dependence on mature trees for nesting, feeding, and shelter. These species also show low tolerance to habitat disturbance. The presence of such forest-dependent birds in the area confirms that the study area has rich characteristics of intact evergreen forest interiors. This highlights the need for conserving this habitat on a priority basis.

Table 6. Association of Species Abundance with Habitat Pressure Variables (Forest Interior Species)

S.No	Bird / Habitat Pressure variable	Deforestation	Fragmentation	Invasive Plants	Human Disturbance
1	Indian Pitta	-0.85	-0.81	0.42	-0.78
2	Malabar Whistling Thrush	-0.82	-0.79	0.40	-0.76
3	Asian Paradise Flycatcher	-0.78	-0.84	0.44	-0.74
4	Brown-cheeked Fulvetta	-0.81	-0.80	0.38	-0.77
5	Tickell's Blue Flycatcher	-0.80	-0.82	0.41	-0.75
6	Orange-headed Thrush	-0.76	-0.78	0.39	-0.72
7	White-bellied Drongo	-0.72	-0.71	0.36	-0.70
8	Greater Racket-tailed Drongo	-0.70	-0.69	0.35	-0.68
9	White-rumped Shama	-0.77	-0.75	0.37	-0.73
10	Heart-spotted Woodpecker	-0.83	-0.82	0.41	-0.79

The above table shows the **Pearson correlation coefficients (r)** between each species' **abundance/encounter rate** and each pressure variable measured across transects.

r ranges are from −1 to +1. Negative r: as the pressure increases (e.g., deforestation), the species' abundance tends to **decrease. Positive r:** as the pressure increases, the species' abundance tends to **increase.**

Strength: $|r| = 0.10–0.29$ = small/ $|r| = 0.30–0.49$ = moderate/ $|r| \geq 0.50$ = strong

A. Deforestation and fragmentation are the dominant drivers (strong negative across all 10 species)

All species show strong negative correlations with Deforestation (≈ −0.70 to −0.85) and Fragmentation (≈ −0.69 to −0.84). The same pattern is seen for forest-dependent insectivores and interior specialists. This is because deforestation reduces habitat area, canopy cover, affects stability of climate and thereby availability of prey. Fragmentation makes the habitat more hotter, drier and windier. It reduces interior forest and breaks movement, which significantly affects insectivores birds.

This finding is similar to earlier findings that forest birds decline with fragmentation and human disturbance. This is because they depend on stable forest microhabitats for foraging and nesting (Beehler et al, 1987).

B. Human disturbance is also strongly negative (nearly as strong as habitat loss)

Human disturbance is consistently negative (≈ −0.68 to −0.79). In forest landscapes, "disturbance" usually means presence of roads and traffic, fuelwood, grazing, noise, visitors and habitat trampling. This finding is similar to studies which indicate that disturbance factors reduce abundance of sensitive forest birds, even when some canopy remains. Disturbance changes understorey structure and increases perceived predation risk (Raman, 2006).

C. Invasive plants show a moderate positive relationship for all 10 species (0.35–0.44)

This is an interesting pattern as Invasive Plants correlate positively with abundance for all birds in the table. However, this does not indicate that invasive plants help biodiversity. But, rather suggests that some amount of growth of invasive plants are creating dense undergrowth which facilitates increase in the population of insects. They also provide a good number of low perches that help insectivores birds.

Studies have shown that in Indian forests, *Lantana camara* growth is linked to lower overall bird richness/diversity at higher densities. However, some species show localized increases. This supports the interpretation that positive correlations can occur for some species even when larger level effect is negative.

Species-level interpretation:

The Strongest "forest-interior sensitivity" signals are seen in:

Indian Pitta (Deforestation −0.85; Fragmentation −0.81; Disturbance −0.78) is an undergrowth preferring insectivore that is strongly tied to shaded, moist leaf-litter microhabitats. Therefore it exhibits a high sensitivity to canopy opening and trampling/disturbance.

Heart-spotted Woodpecker (Deforestation −0.83; Fragmentation −0.82; Disturbance −0.79) Woodpeckers track large trees, snags, and mature structures and therefore fragmentation and extraction reduce nesting opportunities and foraging areas (Ries & Sisk, 2004).

Asian Paradise Flycatcher, Tickell's Blue Flycatcher, White-rumped Shama are insectivores that often use forest edges, but still require woody cover and intact vertical structure of trees for nesting and foraging. They show strong negative values with habitat loss and disturbances.

Relatively less negative but still impacted:

Greater Racket-tailed Drongo, White-bellied Drongo (Deforestation around −0.70 to −0.72; Disturbance around −0.68 to −0.70). Drongos are flexible, but still depend on tree networks, canopy continuity, and stable prey availability and therefore they decline with heavy habitat modification.

The abundance of forest interior bird species is significantly and negatively associated with deforestation, fragmentation, and human disturbance, underscoring the necessity of conserving **contiguous, undisturbed forest habitats** to maintain interior-dependent avifaunal communities.

Fig 1. Heat map showing strength of Association between Abundance of Forest Interior bird species and Habitat Pressure Variables. Warmer Colours Indicate Stronger Negative Associations, While Cooler Colours Indicate Positive Associations

Conclusion

This study gives an assessment of the impact of habitat pressure variables on population abundance of forest interior species. A total of 33 forest-interior bird species were recorded in the study area. This indicates a good canopy structure and high floral complexity in the study area. Nearly 67% of the documented population is Insectivorous species. This reflects high arthropod availability and the presence of a healthy undergrowth. Resident birds formed the majority of the community. 28 resident species were documented, while a few winter migrants were also observed. Overall the forest shows good health, low fragmentation, and stable ecological conditions. The occurrence of indicator and disturbance-sensitive species confirms this. The rich vocal diversity and presence of acoustic specialists shows a well-preserved communication environment in the forest habitat.

The bird community in the study area showed a strong dependence on mature evergreen forest interiors. They also demonstrated low tolerance to habitat disturbance due to human activities. Overall, the forest interiors maintain crucial characteristics of a high-quality habitat. This highlights their importance as a priority conservation zone. Statistical analysis showed strong negative correlations between forest-interior bird populations and human disturbance variables. Deforestation showed the strongest negative effect ($r \approx -0.70$ to -0.85), indicating the high sensitivity of forest interior species to loss of canopy and degradation of habitat. Species abundance is also impacted by fragmentation of habitat by reducing true interior forest conditions. Similarly, human disturbance showed strong negative correlations ($r \approx -0.68$ to -0.79). These impacts are comparable to those caused by habitat loss.

Invasive plant species showed moderate positive correlations ($r \approx 0.35$–0.44), due to increased undergrowth and greater insect availability. However, their long-term ecological effects at the larger community level could be negative. The Indian Pitta and Heart-spotted Woodpecker showed the highest sensitivity to habitat pressures. This makes them strong indicators of forest health and quality of the habitat. Forest insectivores and undergrowth species were more vulnerable to environmental pressures than canopy-dwelling or edge-tolerant species. The numbers of even relatively adaptable birds such as Drongos declined with increasing modifications in habitat due to human disturbance. These findings are in tune with several other ecological studies that showed a declines in forest bird populations due o fragmentation and anthropogenic disturbance. Overall, the results strongly suggest that for sustaining healthy forest-interior bird populations, conservation of large and minimally disturbed forests is essential..

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