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Mixed-species bird flocking in the Himalaya region of India

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Abstract Studying mixed-species bird flocks is crucial as they offer unique insights into interspecific interactions, community structure, and foraging behaviours in complex ecosystems. This study investigates the composition, structure, and behavioural dynamics of mixed-species flocks in the habitats of Majathal Wildlife Sanctuary, Himachal Pradesh. Observations were conducted from 2023 to 2024, with a focus on the non-breeding season, a period marked by heightened flocking activity. A total of 26 bird species forming mixed-species flocks were recorded using point count and line transect methods. Flocks were found to vary in structure, size, and species composition, with all participating birds belonging to the order Passeriformes. Insectivorous species predominated, with omnivorous and nectarivorous types playing supportive roles. Five distinct flocks were identified and analysed for foraging behaviour, vertical stratification, and nucleus species roles. Overall, the study shows that mixed-species flocks in the sanctuary are structured ecological units organized around key nucleus species that coordinate flock behaviour and resource use. These findings are important because they advance our understanding of species interactions in Himalayan ecosystems and provide valuable insights for biodiversity conservation.

Keywords: nuclear species, mixed-species bird flocks, non-breeding period, Majathal Wildlife Sanctuary, Himachal Pradesh

Összefoglalás Ez a tanulmány a különböző madárfajokból álló csapatok összetételét, szerkezetét és viselkedési dinamikáját vizsgálja a Himachal Pradesh-i Majathal Wildlife Sanctuary élőhelyein. A megfigyeléseket 2023 és 2024 között végezték, a költésen kívüli időszakra összpontosítva, amely időszakban ezekre a madárfajokra fokozott csapatos viselkedés jellemző. A vegyes csapatokat alkotó összesen 26 madárfajt regisztráltak pontszámlálással és vonal mentén történő számlálással. A csapatok szerkezetét, méretét és faji összetételét tekintve változatosak voltak, és minden madár a Passeriformes rendbe tartozott. A rovarevő fajok domináltak, míg a mindenevő és a nektárevő fajok másodlagos szerepet játszottak. Öt különböző csapatot azonosítottak és elemeztek a táplálékkereső viselkedés, a vertikális rétegződés és a központi fajok szerepe szempontjából.

Kulcsszavak: központi fajok, vegyes fajösszetételű csapatok, költési időn kívüli időszak, Majathal Wildlife Sanctuary, Himachal Pradesh

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Introduction

Birds typically form intraspecific groups or establish breeding pairs during the breeding season, varying with species-specific behaviour. Mixed-species bird flocks are cohesive associations of two or more bird species that forage and move together, often during non-breeding seasons. The diversity of species, behavioural variation, body size and interspecific dynamics within these flocks are notably diverse (Morse 1977, Greenberg 2000, Bangal *et al.* 2021).

These flocks are common in forested habitats and characterized by the costs and benefits of interspecific interactions that significantly enhance the survival and foraging efficiency of the participating birds (Morse 1977, Sidhu *et al.* 2010). Based on habitat and microhabitat structure, mixed-species flocks in forested areas are more complex (Hariharan *et al.* 2022), often comprising multilevel groups that utilize the understory, midstory, and canopy layers (Mangini *et al.* 2023). Such mixed-species flocking provides multiple advantages, primarily improved foraging success (Goodale & Kotagama 2005) and predator avoidance (Thiollay & Jullien 1998) and improved habitat exploration, driven by the complementary roles of different participating species (Goodale *et al*. 2015). Typically, a large number of insectivorous bird species join these associations. By foraging together in mixed-species groups, these birds are able to locate food resources more efficiently than they would in single-species (intraspecific) groups or while foraging alone (Morse 1970). This is largely due to the collective vigilance of the flock, where certain species act as sentinels, being more alert and frequently giving out alarm calls when threats are perceived. These warning signals benefit all members of the flock, regardless of species, by reducing their individual predation risk (Sridhar *et al.* 2009, Sridhar & Shanker 2014, Borah *et al.* 2017, Sainz-Borgo *et al.* 2018).

Although mixed species flocking provides advantages such as improved foraging and collective vigilance, it also imposes certain costs. Birds in social groups may face increased levels of aggression, heightened competition that can reduce feeding efficiency, and a greater likelihood of attracting predators (Szekely *et al.* 1989, Greenberg 2000, Letten *et al.* 2017). Therefore, the decision to join or remain in a flock reflects a trade-off between these potential disadvantages and the ecological and social benefits of group living (Terborgh 1990).

Within such flocks, a central or focal species, known as the nuclear species, plays a key role in initiating and maintaining flock cohesion. These nuclear species are typically consistent participants and often have a strong influence on the movement and structure of the flock (Sridhar *et al.* 2009). The other participating species, referred to as attendant species, join these flocks opportunistically and benefit from the protection and enhanced foraging opportunities provided by the nuclear species (Goodale & Beauchamp 2010).

The Himalaya mountain range is among the important bird areas having unique avian species. Mixed-species bird flocks play key ecological roles by improving foraging efficiency, reducing predation risk, and structuring avian communities, especially in seasonally variable montane habitats. In the western Himalaya, habitat modification and land-use change may affect the composition and stability of these flocks. This study

examines the composition, structure, and ecological significance of mixed-species flocks during the peak non-breeding season in forested habitats of the Himalayan foothills in Himachal Pradesh.

Material and Methods

Study area

Situated in the Solan and Shimla districts of Himachal Pradesh, Majathal Wildlife Sanctuary, spans approximately 30.86 km^2 (WIIENVIS 2023) *(Figure 1)*. The present study was conducted in lower areas of Chandi beat located in North-Western Himalayan region. The sanctuary comprises subtropical pine forests, mixed deciduous forests, and temperate broadleaf forests, providing diverse habitats for avian species. The study was conducted in multiple habitat types, including forest patches in the sanctuary. The elevation of the study area lies in the range of 1600–1800 m. Surveys focused along walking trails near village borders to cover edge and core habitats.

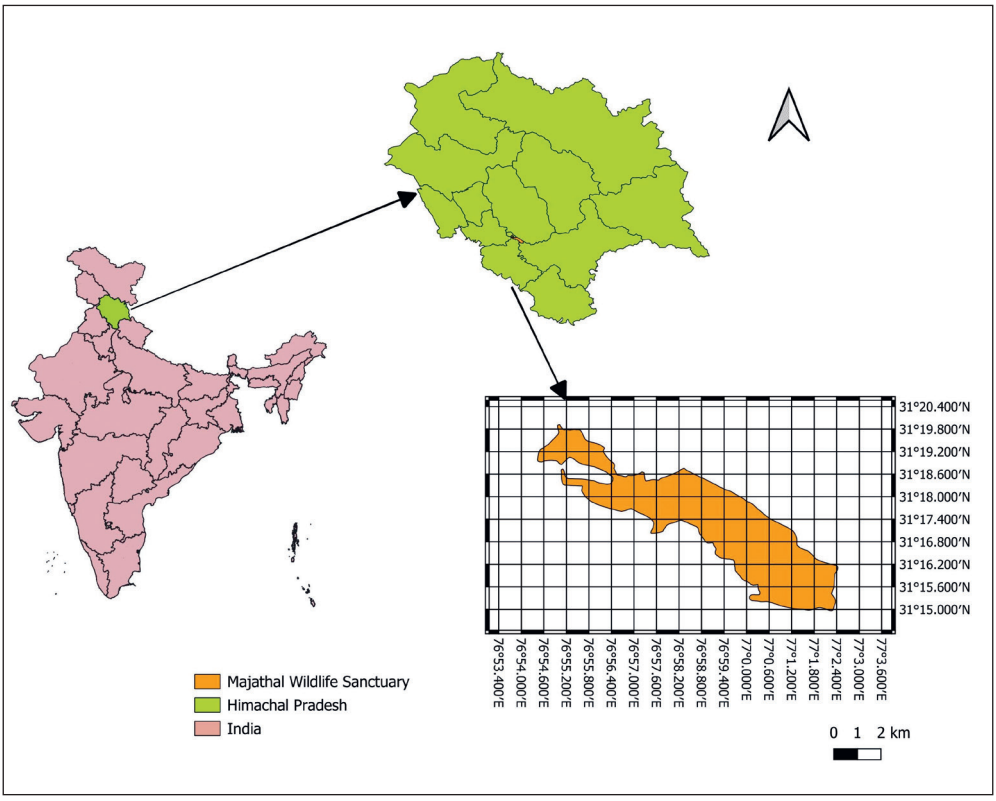

Figure 1. Map of the study area (Majathal Wildlife Sanctuary, Himachal Pradesh)
1. ábra A kutatási terület (Majathal Wildlife Sanctuary, Himachal Pradesh) térképe

Methodology

Field surveys were conducted from October 2023 to April 2024, as this period coincides with the non-breeding season of most forest bird species, when flocking activity is highest. Post monsoon is the time of non-breeding. Point count and line transect methods were mainly employed to record bird species participating in mixed-species flocks. Observations were made during peak bird activity hour in the morning (06:00–08:00 AM) and evening (04:00–06:00 PM) to ensure accurate documentation of flock dynamics. Key parameters recorded included species identity and number, flock size and composition, focal or nucleus species, and interspecific interactions. Species richness, diversity indices (Shannon–Weaver index and Simpson index of diversity), and statistical analyses were performed using PAST (3.22 version) software. The role of nucleus species was identified based on the frequency and consistency of their presence in flocks.

Results

Species composition and flock structure

A total of 26 species were observed participating in mixed-species flocks. All belonged to the order Passeriformes, distributed across 10 avian families: Corvidae, Paridae, Cisticolidae, Pycnonotidae, Phylloscopidae, Zosteropidae, Leiothrichidae, Nectariniidae, Prunellidae and Fringillidae. During the study period, a total of 31 flocks were recorded, and their frequency varied among them. Flock A was observed more frequently than the others. Five representative flock types (A–E) were identified based on consistent association patterns (*Table 1)*. Flock C demonstrated the highest species richness (S = 8), comprising both common associates like the Cinereous Tit *(Parus cinereus)* and rarer participants such as the Speckled Piculet *(Picumnus innominatus)* and Black-throated Accentor *(Prunella atrogularis)*. Flocks A, D and E each contained four species, comprising smaller flock size or a more selective association in certain habitat strata.

Notably, the Himalayan Bulbul *(Pycnonotus leucogenys)* was present in both Flock A and Flock E. It is a frequent associate or semi-focal species found. The species composition shows a dynamic interspecific flocking pattern, with some species serving as consistent nucleus members (Grey-hooded Warbler *Phylloscopus xanthoschistos* in Flocks B and C) and others as transient joiners.

Foraging ecology and focal species roles

The flocks exhibited distinct foraging height preferences and substrate usage, indicating vertical and horizontal niche partitioning to minimize interspecific competition *(Table 2)*. Flocks B and C primarily foraged in the understorey to midstorey, favoring foliage and twigs, whereas Flocks D and E utilized higher strata (midstorey to canopy) and more structural substrates like branches, with Flock E focusing on nectar-feeding from flowers,

Table 1. Species composition of mixed-species flocks
1. táblázat A vegyes csapatok fajösszetétele

Flock A	Flock B	Flock C	Flock D	Flock E
Himalayan Bulbul ***(****Pycnonotus leucogenys****)***	*Lemon-rumped Warbler (Phylloscopus chloronotus)*	Cinereous Tit *(Parus cinereus)*	Grey Tree Pie *(Dendrocitta formosae)*	Crimson Sunbird *(Aethopyga siparaja)*
Himalayan Prinia ***(****Prinia crinigera)*	Chestnut-throated Minla *(Actinodura strigula)*	Pink-browed Rosefinch *(Carpodacus rodochroa)*	Black-headed Jay *(Garrulus lanceolatus)*	Black Bulbul *(Hypsipetes leucocephalus)*
Red-vented Bulbul ***(****Pycnonotus cafer****)***	Oriental White-eye *(Zosterops palpebrosus)*	Himalayan Black-lored Tit *(Machlolophus xanthogenys)*	Large-billed Crow *(Corvus macrorhynchos)*	Himalayan Bulbul *(Pycnonotus leucogenys)*
Rufous-breasted Accentor ***(****Prunella strophiata)*	Whiskered Yuhina *(Yuhina flavicollis)*	Green-backed Tit *(Parus monticolus)*	Rufous Sibia *(Heterophasia capistrata)*	Oriental white-eye *(Zosterops palpebrosus)*
–	Grey-hooded Warbler *(Phylloscopus xanthoschistos)*	Grey-hooded Warbler *(Phylloscopus xanthoschistos)*	–	–
–	Red-billed Leiothrix *(Leiothrix lutea)*	Black-chinned Babbler *(Cyanoderma pyrrhops)*	–	–
–	–	Black-throated Accentor *(Prunella atrogularis)*	–	–
–	–	Speckled Piculet *(Picumnus innominatus)*	–	–

Table 2. Foraging behaviour of five main flock types
2. táblázat A csapatok karakterisztikája különböző paraméterek alapján

Parameter	Flock A	Flock B	Flock C	Flock D	Flock E
Foraging Height	Midstorey	Understorey	Understorey or Midstorey	Midstorey or Canopy	Midstorey or Canopy
Foraging Ground	Branch/Foliage	Foliage	Twigs/Branch	Twigs/Branch	Branch (Nectar Feeding)
Focal Species	Himalayan Bulbul	Grey-hooded Warbler	Cinereous Tit	Grey Tree Pie	Oriental White-eye

an adaptation aligned with the presence of Crimson Sunbird *(Aethopyga siparaja)* and Black Bulbul *(Hypsipetes leucocephalus)*. The designated focal species for each flock, such as Cinereous Tit, Oriental White-eye *(Zosterops palpebrosus)* and Grey Tree Pie *(Dendrocitta formosae)* played a central role in maintaining flock cohesion and often led movements across strata. These focal species serve as informational hubs, guiding group foraging decisions

and potentially reducing predation risk through increased vigilance. Their strata-specific leadership also reflects adaptations to resource availability and microhabitat preference in the Himalayan landscape.

Table 3. Results of the analysis of flock diversity indices
3. táblázat A csapatok diverzitás indexeinek elemzésének eredményei

Metrics / Flocks	Frequency of each flock	Species richness (S)	Total individuals of all species in each flock (N)	Simpson diversity index (1-D)	Shannon diversity index (H')
A	9	4	10	0.70	1.27
B	6	6	16	0.79	1.68
C	5	8	21	0.82	1.91
D	7	4	18	0.73	1.35
E	4	4	12	0.73	1.35

Flock diversity

Quantitative analysis revealed significant variation in species diversity across the five flock types *(Table 3)*. Flock C emerged as the most diverse group, with the highest species richness (S = 8), Simpson diversity index (1–D = 0.82), and Shannon diversity Index (H′ = 1.91) *(Figure 2)*. This suggests both a high number of species and evenness in their relative abundance. Flock B, although slightly less rich, also exhibited high diversity

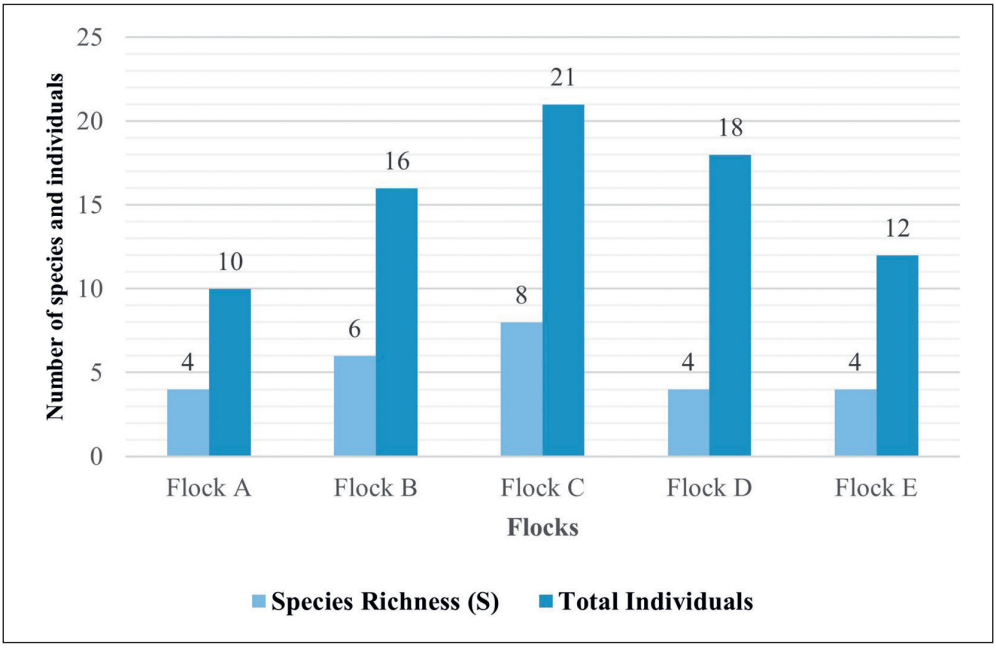

Figure 2. Representation of species richness and total individuals of all species in each flock
2. ábra Az egyes csapatok fajgazdagságának és az összes faj összes egyedének reprezentációja

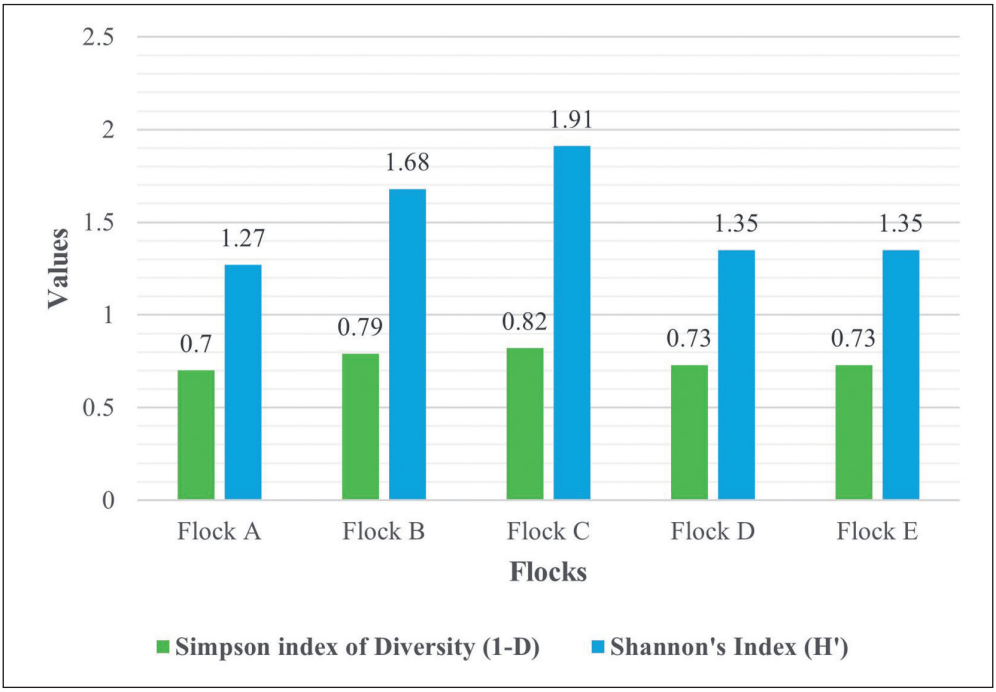

Figure 3. Representation of values of Simpson index of diversity and Shannon's index by flocks
3. ábra A Simpson és a Shannon indexek értékei csapatonként

(H′ = 1.68) and a relatively balanced structure (1–D = 0.79). In contrast, Flock A had the lowest diversity scores (H′ = 1.27, 1–D = 0.7), reflecting fewer species and/or dominance of one or two individuals *(Figure 3)*. These indices underline the ecological variability of flocks possibly influenced by habitat structure, resource distribution, and species-specific flocking tendencies. The higher values in Flock C diversity (1–D = 0.82 and H′ = 1.91) are attributed to its varied foraging height, heterogeneous substrate use, and inclusion of both common and rare associates, facilitating resource complementarity.

Feeding guild

Analysis of the observed flocks shows that flocks B and C were characterized by a high frequencies of insectivores. These flocks exhibited well-structured formations and strong interspecific cohesion, driven by cooperative foraging strategies such as foliage gleaning and joint predator vigilance. The presence of multiple understorey insectivores in these flocks shows insectivorous species form the nucleus of flocks, promoting stability and synchronicity during foraging movements. In contrast, Flock D consisted exclusively of omnivorous species such as the Grey Tree Pie, Black-headed Jay *(Garrulus lanceolatus)*, and Large-billed Crow *(Corvus macrorhynchos)*. This flock exhibited relatively loose coordination, form under different ecological conditions, possibly in edge or disturbed habitats where resource availability is patchier. The absence of strict trophic or behavioural

specialization among flock members reduce the need for coordinated movements, resulting in more fluid associations.

Flock E presented a mixed foraging guild, with species such as the Crimson Sunbird contributing a nectarivorous component. This heterogeneity implies diverse resource exploitation, including nectar, fruits, and insects. The vertical foraging spread ranged from the midstorey to the canopy and included both generalist omnivores and specialized nectarivores in habitat patches with flowering and fruiting vegetation.

Ecological implications and interactions

The species composition showed a dynamic pattern of interspecific flocking, with some species occurring consistently in nucleus positions and others joining transiently. The Grey-hooded Warbler and Cinereous Tit were recorded as focal species across multiple flocks, frequently occupying central positions. The vertical foraging spread ranged from the midstorey to the canopy. Both generalist omnivores and specialized nectarivores were present. These flocks were observed in habitat patches containing flowering and fruiting vegetation.

Discussion

The study confirms the ecological significance of mixed-species flocks in post-monsoon habitat conditions. The dominance of insectivorous species indicates that flocking enhances foraging success in complex forest strata. Presence of nucleus species like Cinereous Tit and Grey-hooded Warbler suggests species-specific leadership roles based on alertness, mobility, or vocalisation frequency.

The present study recorded a high prevalence of insectivorous species in mixed-species flocks, consistent with findings by Macdonald and Henderson (1975) and Sridhar *et al.* (2009). However, some flock participants were omnivores and nectarivores, as also reported by Srinivasan *et al.* (2012) in a tropical forest in northeastern India. The study by Satish *et al.* (2025) in Western Himalaya, highlights that insectivore abundance decreases with increasing human disturbance, which is accompanied by a corresponding decline in foliage arthropod availability. The formation of mixed-species bird flocks can enhance foraging efficiency and rate, potentially contributing to biological pest control, as suggested by Sinu (2011). Parids species have also been identified as nuclear species in mixed-species flocks, as highlighted by Dolby and Grubb (1999). The participation of *Parus* spp. and *Phylloscopus* spp. in mixed-species flocks was also observed in a study by Macdonald and Henderson (1975) in Kashmir.

Flocks varied not only in taxonomic richness but also in vertical niche partitioning, reflecting stratified foraging strategies that minimize interspecific competition (Sidhu *et al.* 2010, Srinivasan *et al.* 2012, Hariharan *et al.* 2022). The understory and canopy emerged as the most frequently utilized strata in the present study, also noted by Gupta *et al.* (2024), indicating that these layers likely offer optimal arthropod prey availability. This pattern is further supported by the observations of Mangini *et al.* (2023), reinforcing the importance of vertical habitat structure in shaping flock composition and foraging dynamics. However, as highlighted by

Greenberg (2000), participation in flocks involves trade-offs. While the benefits include increased foraging efficiency and predator detection, costs such as intraspecific aggression, competition for resources, and increased predator visibility were likely, especially in larger or more stratified flocks like C and B. This cost-benefit balance governs flock membership and fluidity, a pattern supported by the variation in diversity metrics observed here. Behavioural observations revealed coordinated movement, alarm calling, and food patch sharing, suggesting mutualistic advantages and reduced vigilance burden per individual.

Conclusion

The study demonstrates that mixed-species flocking in Majathal Wildlife Sanctuary is structurally and behaviourally complex, governed by ecological constraints and interspecific facilitation. Flock composition, focal species presence, and habitat utilization are all tightly interlinked, highlighting the adaptive value of flocking as a survival strategy during the non-breeding season in montane ecosystems. These findings contribute to a broader understanding of avian community dynamics in the Western Himalayas and lay the groundwork for future longitudinal and seasonal studies. The loss of key species from mixed-species flocks due to anthropogenic habitat disturbances could potentially diminish the fitness and survival prospects of numerous other associated species. Future research may explore seasonal shifts in flock dynamics and long-term monitoring to assess climate and habitat change impacts.

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