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Cover: Digital illustration of *Impatiens chamchumroonii* in Krita by Dupati Poojitha.

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ARTICLE

Foraging niche segregation among woodpeckers in the oak-pine forest of Kumaon Himalaya, Uttarakhand, India

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Abstract: Understanding how species that share the same habitat coexist can reveal how niche segregation helps reduce competition and structure communities. This study examines foraging niche segregation among six woodpecker species: Brown-fronted Woodpecker *Dendrocoptes auriceps*, Himalayan Woodpecker *Dendrocopos himalayensis*, Grey-headed Woodpecker *Picus canus*, Scaly-bellied Woodpecker *Picus squamatus*, Greater Yellownape *Chrysophlegma flavinucha*, and Lesser Yellownape *Picus chlorophus* in the oak-pine forests of Ranikhet, Kumaon Himalaya, Uttarakhand. Opportunistic observations were conducted to determine key foraging niche dimensions, including foraging tree diameter, foraging height, substrate type, vertical position, and the condition of foraging trees and substrate. The analysis indicates that these woodpecker species exhibit distinct foraging preferences concerning substrate use, foraging height, and vertical stratification, while they did not seem to respond to the presence of dead substrate. Notably, the Grey-headed and Scaly-bellied Woodpeckers, unlike the other species that primarily forage on trees, exhibited a preference for lower foraging heights and were frequently observed foraging on the ground.

Keywords: Competition, deadwood conservation, foraging behavior, picidae, snags, substrate condition, sympatry, vertical stratification, woodpeckers.

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Author details: Rafat Jahan is a UGC NET-JRF fellow in the Department of Wildlife Sciences at Aligarh Muslim University. She is pursuing her doctoral research on woodpeckers in the Kumaon Himalaya focusing on their ecology and behavior. Her thesis investigates the ecological roles and behavioral adaptations of woodpeckers in this region. Satish Kumar is a professor at Aligarh Muslim University and Chairperson of the Department of Wildlife Sciences. His research specializes in large carnivore ecology, with a focus on predator-prey relationships involving the Grey Wolf, Blackbuck and livestock studied through radio-telemetry. He has also investigated the migratory behavior of Bar-headed Geese between their wintering and breeding ranges using satellite telemetry. Over the years, he has mentored students on a wide range of topics in wildlife science and conservation. Dr. Kaleem Ahmed is an assistant professor in the Department of Wildlife Sciences at Aligarh Muslim University. His research spans diverse areas of wildlife ecology, with a current focus on leopards in conflict zones of western Uttar Pradesh and the impacts of heat stress on birds using remote sensing and GIS technology. He is also engaged in studies on avian ecology in the Himalayan region.

Author contributions: RA: field work, manuscript draft. SK: conceptualization, methodology, supervision and editing of manuscript. KA: conceptualization, supervision, evaluation, editing and proof reading.

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INTRODUCTION

Banj Oak *Quercus leucotrichophora* and Chir Pine *Pinus roxburghii* forests occupy a distinct mid-elevation vegetation zone (1500–2200 m) in the western Himalaya. In contrast to Chir Pine forests, which are rather dry and have a simpler structure, oak forests, with their damp microclimate, dense understory, epiphyte-rich vegetation, and cavity-bearing trees, are more complex. Together, these forests form a mosaic crucial for sustaining avian communities, including several woodpecker species (Shahabuddin et al. 2017). Understanding the segregation of woodpeckers within this oak-pine forest is key to explaining how they coexist in a landscape like Ranikhet, since the woodpeckers are primary cavity excavators and resource partitioners.

The current ecological study on woodpeckers focuses on the mechanism of species coexistence within communities. Coexistence becomes much more challenging in the case of sympatric species, which are ecologically and morphologically similar (Johnson & Bronstein 2019). The theoretical basis for understanding species coexistence within ecological communities is provided by the ecological niche idea as an n-dimensional hypervolume that includes the resources and environmental conditions that allow a species to persist (Hutchinson 1957). Gause (1934) was the first to experimentally show the competitive exclusion principle, which states that two species with the same ecological requirements cannot coexist indefinitely because one will eventually outcompete the other for shared limiting resources. These ideas have been improved by modern coexistence theory, which finds that stable species coexistence happens when niche differences are sufficient to offset any inherent fitness differences between competitors (Chesson 2000).

Niche partitioning (or niche segregation) is the main stabilizing mechanism that allows biodiversity to be maintained in natural communities by minimizing direct competition between coexisting species through differential resource utilization, spatial or temporal habitat use, or through other ecological dimensions (MacArthur & Levins 1967). The niche theory of competition assumes that exploitation of resources, prey species, food, or habitat type is the primary determinant of ecological segregation. It predicts that coexisting species should differ in ecological, morphological, or behavioural characteristics to minimize competition (Zeng & Lu 2009). To address this pressing issue in ecology, many ecologists have suggested the importance of niche segregation as a significant factor in reducing interspecific competition (Gamboa & Brown 1976; Bull et al. 1986). It has been demonstrated over time by field and laboratory observations, mathematical models, and the segregation of shared resources that coexisting species reduce the consequences of interspecific competition.

The concepts of sympatry, resource partitioning, and coexistence have also been studied extensively in various woodpecker species (Williams 1975; Short 1978; Torok 1990). They may live in a wide range of habitat types due to their morphological variation in size, and segregation by size may also be a crucial component in sympatric species coexistence (Winkler & Christie 2002). Tropical rainforests harbour the most significant number of woodpeckers. The most diverse forests are found in southeastern Asia and South America, where up to 13 species can coexist in sympatric communities within 100 ha or less. Woodpeckers are highly specialized in more or less similar ways, and it could be challenging to separate their habitat (Short 1978).

Even so, as many as 15 woodpecker species were observed coexisting in sympatry in the deciduous Sal forests of sub-Himalayan regions (Kumar et al. 2020). They segregated their foraging niche based on tree size, foraging height, utilization of live and dead trees, borer-infested vegetation, open spaces, and canopy cover. Santharam (1995) studied how eight woodpecker species in the Western Ghats segregate foraging niches, and found evidence of size-related preference in substrate sizes. However, with a few notable exceptions (Mikusiński 2006), the ecology of woodpecker foraging has not received much attention in tropical and subtropical regions with a high woodpecker diversity.

Recent studies highlight how resource partitioning enables woodpecker coexistence in forested landscapes. Si et al. (2023) found that sympatric woodpeckers in northeastern China segregated their niches according to substrate type, tree condition, DBH, and foraging height, with larger species preferring snags and trunks while smaller species used canopy branches. Similarly, Pradhan et al. (2025) discovered that woodpeckers in the non-protected forest of the eastern Himalaya showed elevation-dependent changes in foraging strategies, vertical stratification, and body size-driven segregation, with tropical forests supporting higher diversity. Both studies emphasize that in order to sustain diverse woodpecker communities, structural heterogeneity is essential, including the presence of large old huge trees as well as snags.

The present study was conducted to investigate how woodpeckers segregate within the oak-pine forest of Ranikhet, which is crucial to understanding their coexistence in this landscape.

METHODS

Study area

The research was carried out in Ranikhet Cantonment Forest. The study area is situated in the Uttarakhand Pali sub-division of the Almora District, falling within the boundaries of Ranikhet Cantonment. Three distinct areas make up the Cantonment: Chaubatia (2,125 m), Deolikhet (1,823 m), and Alma Barrack (1,818 m). The majority of the area near Ranikhet is a protected reserve forest covering a stretch of ridges with rounded or flat tops, subsidiary spurs, and slopes with a mild to moderate gradient. Deep, well-drained soils have developed as a result of the moderate slopes. The terrain is undulating and crisscrossed by small streams (Mani 1981).

The Ardee Estate Bungalow, a guest house affiliated with Aligarh Muslim University, is a well-known property in Ranikhet, Uttarakhand, that provides academic visitors with a pristine environment dominated by oak-pine forests. The Ardee Estate was designated as the central point of the study area, encompassing a 3-km radius. This area was selected as a reasonable spatial limit for conducting intensive research. Using Google Earth Pro, the study area was precisely mapped, and the boundaries of the study site were drawn (Image 1).

Data collection

Field observations were carried out over a period of 16 months (November 2022–May 2024), except for the monsoon months (July 2023–September 2023), by the first author. Birds were located by searching in different patches of Oak and Chir-Pine forests, usually an hour after sunrise, and continued until sunset. Opportunistic observations were also recorded during the study. While observations were conducted throughout the day, most were taken in the early morning or late afternoon hours, when foraging activity was at its highest. During the study period, approximately 240 cumulative field

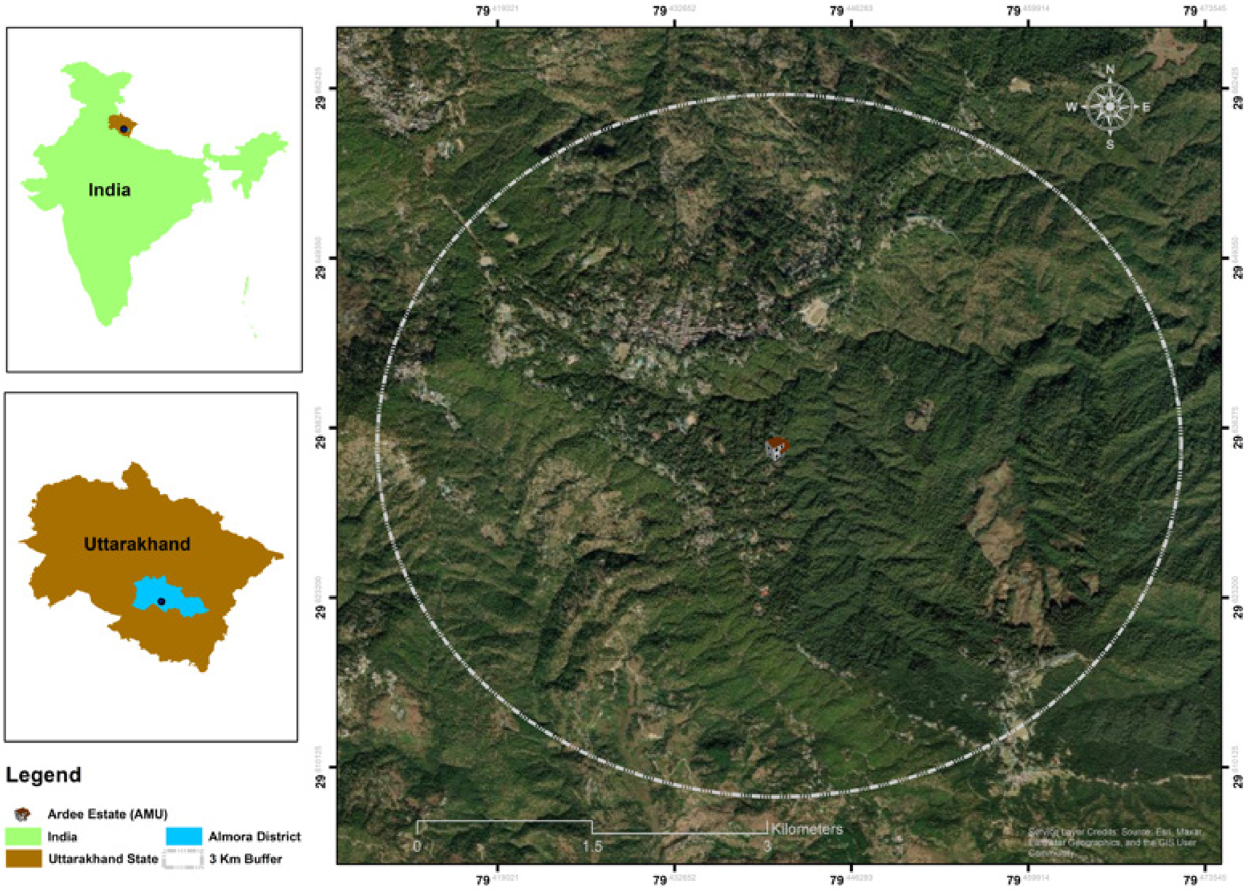

Image 1. Map showing the location of the study area.

days were spent in the study area, with an estimated 1,440 h of observation time. When a woodpecker was detected, records were made of the species, foraging behavior, foraging time, and the characteristics of the trees it foraged on. Repeated observations of the same individual were avoided to ensure sample independence. A woodpecker was only included in a second observation if it had moved at least 100–150 m from its original location. A minimum viewing distance of 10 m was maintained to avoid disturbance to woodpeckers.

Foraging behavior parameters

For every foraging observation, the following parameters were noted: foraging behavior (see below), foraging height, and substrate (ground, tree or tree branch). The following criteria were used to distinguish the foraging behavior (Remsen & Robinson 1990): (1) pecking: pecking at a branch or tree trunk where wood chips or tiny pieces of bark fall; (2) excavating: using its beak to make a hole so that big wood and bark fragments can fall from it; (3) probing: searching for food by probing and looking through any gaps or sutures in a tree; (4) gleaning: searching over trunk and limb surfaces; (5) flycatching/eating: the pursuit of insects in flight; and (6) ground foraging.

Foraging tree attributes

The attributes of the trees included the species of tree being foraged upon, girth at breast height (GBH), the height of the tree (measured using Nikon Forestry Pro II laser rangefinder/hypsometer), the tree canopy cover (measured by gridded mirror method), and substrate and tree condition. The tree condition was classified as: (1) live: standing and growing trees, (2) dead: trees standing in the forest with branches intact but otherwise dead, (3) snag: trees standing in the forest with boles that were completely dead. However, dead trees and snags were clubbed together and designated as dead. The substrate condition was thus classified as: (1) Live, (2) Dead (~75% of the substrate in use was completely dead).

Niche overlap

Niche overlap among the six woodpecker species was measured using Pianka's index in EcoSim 7.0 software (EcoSimPro/PROOSIS 2024, Version 7.0). The Pianka index measures the degree to which two different species overlap in their use of similar resources and is estimated by using the formula:

$$O_{jk} = \frac{\Sigma_i p_{ij} p_{ik}}{\sqrt{\Sigma_i p_{ij}^2 \Sigma_i p_{ik}^2}}$$

where p_{ij} and p_{ik} represent the proportional use of resource *i* by species *j* and *k*, respectively. The index ranges from 0 (no overlap) to 1 (complete overlap). Using the RA3 algorithm, which maintains the niche breadth of each species while reshuffling resource use, EcoSim randomly generated 1000 iterations of the resource use matrix to see if observed overlaps differed from random expectations. Then, the observed values were compared to null distributions to determine whether there was a significantly higher overlap (shared resource use) or a smaller overlap (niche segregation).

Correlation between woodpecker morphology and foraging variables

To know whether woodpeckers had a tendency to forage on tree diameters based on their body weights, the correlation between the mean DBH of trees used for foraging by each species and their corresponding body weights were calculated. Likewise, a correlation between body weight and mean foraging height was also assessed. Body weight of woodpeckers was obtained from Winkler et al. (1995).

Data analysis

Analysis was done for those species for which at least ten observations were available. The continuous data were evaluated using the Kruskal-Wallis test (such as foraging tree diameter and its height). On the other hand, categorical variables (i.e., vertical position, foraging behavior, tree and substrate condition) were evaluated using chi-square tests. Two steps were used to investigate the segregation of foraging niches along individual dimensions. First, it was evaluated whether there were differences among species in each of the dimensions related to foraging. A second-level analysis of pairwise species comparison was conducted if differences were statistically significant, using the post-hoc Dunn's test (for continuous variables) and chi-square test (for categorical variables) with Bonferroni adjustments for multiple comparisons.

R software (R Core Team 2024, version 4.4.1) in Rstudio (version 2024.12.1 +563) was used for all the graphical representation and statistical analysis using the following packages: ggplot2 (3.5.1) (Wicham 2016), vegan (2.6-8) (Oksanen et al. 2024). The EcoSim 7.0 software used Pianka's indices to measure the niche overlap.

RESULTS

A total of 1,006 foraging observations on six species of woodpeckers were collected, including 387 for Brown-fronted Woodpeckers *Dendrocoptes auriceps*, 233 for Grey-headed Woodpeckers *Picus canus*, 182 for Greater Yellownape *Chrysophlegma flavinucha*, 142 for Himalayan Woodpeckers *Dendrocopos himalayensis*, 32 for Scaly-bellied Woodpeckers *Picus squamatus* and 30 for Lesser Yellownape *Picus chlorophus* (Table 1). Four additional species (i.e., Speckled Piculet *Picumnus innominatus*, Rufous-bellied Woodpecker *Dendrocopos hyperythrus*, Fulvous-breasted Woodpecker *Dendrocopos macei*, and Greater Flameback *Chrysocolaptes guttacristatus*) were also sighted. However, they were not included in the analysis due to a low sample size (< 10).

Foraging behavior differed among six woodpecker species

The six woodpecker species differed significantly in their foraging behavior ($\chi^2 = 424.3$; df = 25; $p < 0.001$). Both the Brown-fronted and Himalayan Woodpeckers exhibited various foraging behaviours. Pecking was the most preferred (58.4% and 54.9% of foraging observations, respectively), followed by probing (18.1% and 16.9%, respectively), gleaning (15.5% and 21.1%, respectively) and excavating (15.5% and 7%, respectively). Ground foraging was only observed in Grey-headed and Scaly-bellied Woodpeckers (45.5% and 40.6%, respectively). All pairwise species comparisons of foraging behaviour showed significant differences, except for the Himalayan Woodpecker & Lesser Yellownape, the Grey-headed Woodpecker & Scaly-bellied, and Brown-fronted Woodpecker & Greater Yellownape (Table 2). Pecking was the most common foraging behaviour exhibited by all the woodpeckers except the Grey-headed Woodpecker (Figure 1).

Species pairs differed significantly in vertical positioning with respect to strata, i.e., portions of a tree utilized for foraging ($\chi^2 = 563.69$; df = 25; $p < 0.001$). Compared to the Grey-headed Woodpecker and Lesser Yellownape, the other four species used the trunk more often (Brown-fronted Woodpecker, 70%; Himalayan Woodpecker, 68.3%; Scaly-bellied Woodpecker, 43.7%; Greater Yellownape, 47.3%). The Grey-headed Woodpecker was predominantly observed foraging on the ground (45.5%), whereas the Lesser Yellownape showed greater use of the lower canopy (60%). The Grey-headed and Scaly-bellied Woodpecker species pairs did not differ significantly, while the other pairs did (Table 3).

Foraging tree attributes differences among six woodpecker species

Among the six woodpecker species, significant differences were observed in the selection of foraging tree species ($\chi^2 = 674.74$, df = 50, $p < 0.001$). The Grey-headed and Scaly-bellied Woodpeckers primarily foraged on the ground (45.5% & 40.6%, respectively) but also utilized tree species such as pine (27.5% & 37.5%, respectively), oak (13.3% & 0%, respectively), Kaafal *Myrica esculenta* (5.2% and 3.1%, respectively), and Deodar *Cedrus deodara* (3.9% and 18.8%, respectively). The Brown-fronted Woodpecker exhibited a strong preference for pine trees *Pinus roxburghii*, with 90.2% of its foraging activity occurring on this species. Similarly, the Himalayan Woodpecker and Greater Yellownape primarily foraged on pine trees (57% and 55%, respectively), followed by oak trees (24.7% & 21.4%, respectively), with occasional use of other species such as Kaafal, rhododendron *Rhododendron arboreum*,

Table 1. Size categories and species codes considered for this study. Species are arranged from smallest to largest (Body weights taken from Winkler et al. 1995).

Species	Code	Size category	Foraging observations (No.)	Body weight (g)
Brown-fronted Woodpecker *Dendrocoptes auriceps*	DEAU	Small	387	44.5
Himalayan Woodpecker *Dendrocopos himalayensis*	DEHI	Medium	142	73
Lesser Yellownape *Picus chlorophus*	PICH	Medium	30	79
Grey-headed Woodpecker *Picus canus*	PICA	Large	233	152.5
Greater Yellownape *Chrysophlegma* (*Picus*) *flavinucha*	PIFL	Large	182	181.5
Scaly-bellied Woodpecker *Picus squamatus*	PISQ	Large	32	182

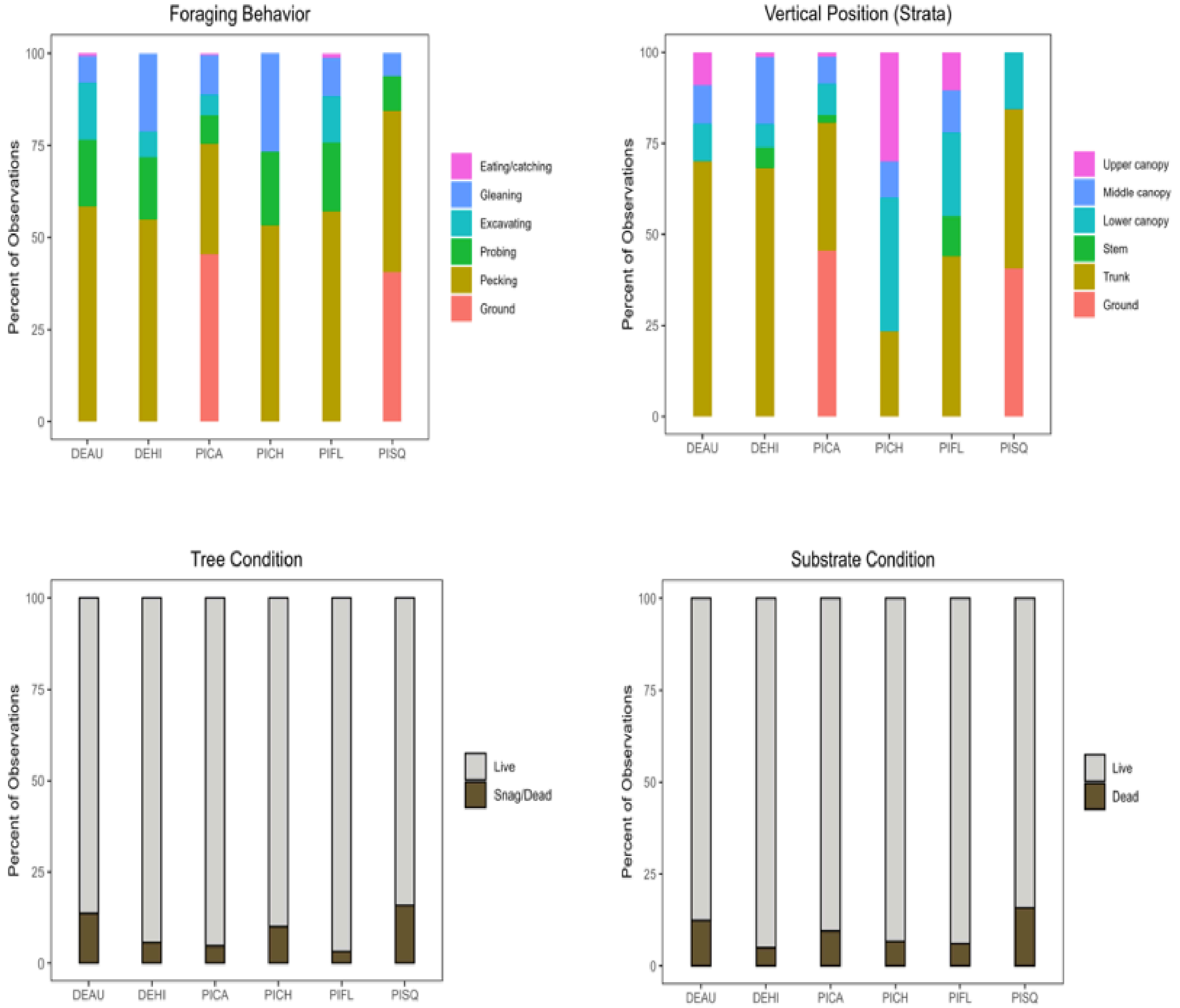

Figure 1. Frequency of foraging observation of six woodpecker species, categorized by foraging behavior (top left), vertical position (strata) (top right), tree condition (bottom left), and substrate condition (bottom right). Refer Table 1 for species codes.

Table 2. Differences in foraging behavior between species pairs (below diagonal). The table shows the chi-squared test p-value. Significant differences were at α = 0.05. Refer Table 1 for species codes.

	DEAU	**DEHI**	**PICA**	**PISQ**	**PIFL**	**PICH**
DEAU						
DEHI	**<0.001**					
PICA	**<0.001**	**<0.001**				
PISQ	**<0.001**	**<0.001**	0.495			
PIFL	0.655	**0.036**	**<0.001**	**<0.001**		
PICH	**<0.001**	0.457	**<0.001**	**<0.001**	**0.050**	

and eucalyptus *Eucalyptus* spp.. There were significant differences in the selection of foraging tree species among all species pairs (Table 4, above diagonal).

There were significant differences among the six woodpecker species in their use of live and dead (snag) trees for foraging ($\chi^2 = 35.487$, df = 10, $p < 0.001$). While all species primarily foraged on live trees, the Brown-fronted Woodpecker and Scaly-bellied Woodpecker

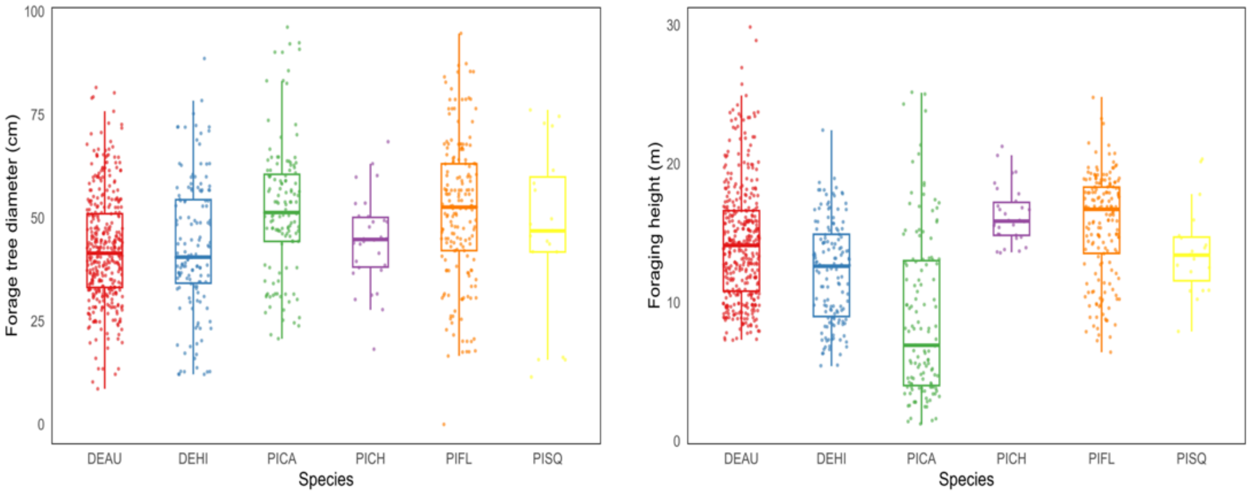

Figure 2. Comparison of forage tree diameter (cm) and foraging height (m) among six woodpecker species. Boxplots display observed values and distribution ranges, excluding outliers, using dots and whiskers. Horizontal lines represent medians, while boxes indicate the interquartile range (middle 50% of values). Refer Table 1 for species codes.

Table 3. Differences in vertical position(strata) between species pairs (below diagonal). The table shows the chi-squared test p-value. Significant differences were at α = 0.05. Refer Table 1 for species codes.

	DEAU	DEHI	PICA	PISQ	PIFL	PICH
DEAU						
DEHI	**<0.001**					
PICA	**<0.001**	**<0.001**				
PISQ	**<0.001**	**<0.001**	0.344			
PIFL	**<0.001**	**<0.001**	**<0.001**	**<0.001**		
PICH	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.013**	

Table 4. Differences in the foraging tree condition (below diagonal) and foraging tree species (above diagonal) between species pairs. The table shows the chi-squared test p-value. Significant differences were considered at α = 0.05. Refer Table 1 for species codes.

	DEAU	DEHI	PICA	PISQ	PIFL	PICH
DEAU		**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
DEHI	**0.005**		**<0.001**	**<0.001**	**<0.001**	**<0.001**
PICA	0.207	0.095		**0.021**	**<0.001**	**<0.001**
PISQ	0.948	0.056	0.123		**<0.001**	**<0.001**
PIFL	**<0.001**	0.176	0.652	**0.044**		**<0.001**
PICH	0.669	0.363	**0.009**	0.172	**0.009**	

used snags/dead trees more for foraging than others, accounting for 13.7% and 15.8% of their foraging activity, respectively (Figure 1, bottom left). Significant differences in tree usage were observed between the Brown-fronted and Greater Yellownape, as well as between the Brown-fronted and Himalayan Woodpecker. Foraging tree usage did not differ significantly among other species pairs (Table 4, below diagonal).

Woodpeckers utilized forage trees with GBH ranging 8.6–96.18 cm. The average GBH of trees used for foraging varied among species, with the Brown-fronted Woodpecker *Dendrocoptes auriceps* foraging on trees with an average GBH of 42.52 cm, while the Grey-headed Woodpecker *Picus canus* selected trees with an average

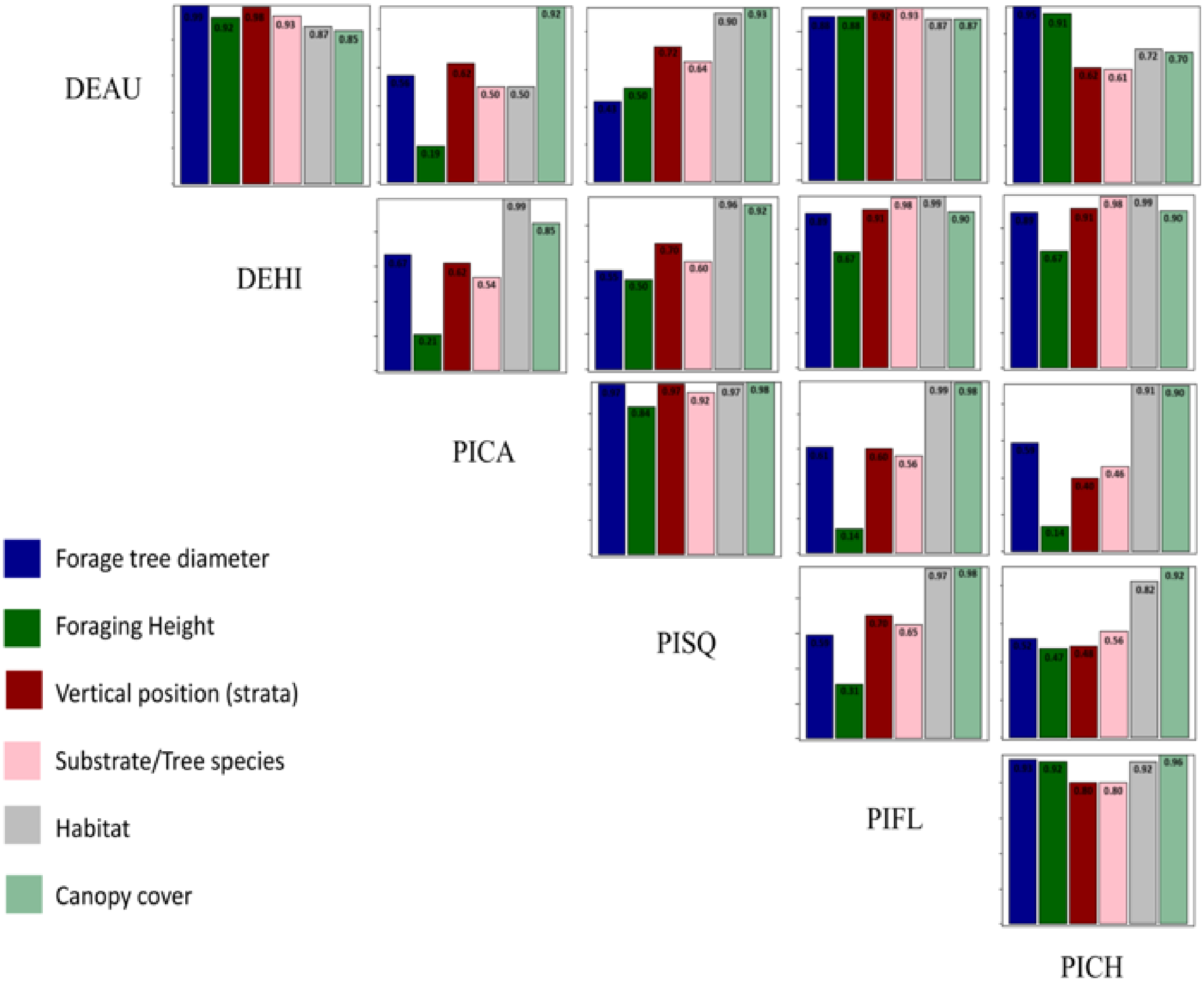

Figure 3. Overlap in foraging niches between woodpecker species pairs for individual foraging dimensions. The y-axis scale represents overlap values, ranging from 0 (no overlap) to 1 (complete overlap). The x-axis scale represents the individual foraging dimension shown in legends. Refer Table 1 for species codes.

GBH of 52.10 cm (Figure 2).

The diameter of the trees used for foraging differed significantly between the species (H = 71.511, df = 5, p < 0.001). When comparing species pairs, it was observed that larger-bodied species (Grey-headed Woodpecker & Greater Yellownape) picked larger trees for foraging. In contrast, smaller woodpeckers (Brown-fronted Woodpeckers) chose smaller tree diameters. The preference of the medium-sized woodpecker (Himalayan Woodpecker) for foraging tree diameter was similar to that of the smaller species (Brown-fronted Woodpecker). Although having a large size, Scaly-bellied Woodpecker did not significantly differ from any other woodpecker species in its choice of foraging tree diameter (Figure 2, left; Table 5, below diagonal).

All woodpeckers were found to be foraging from the ground to a height of around 30 m in this study. The height at which each species foraged differed significantly (H = 150.07, df = 5, p < 0.001). Often observed on the ground, Grey-headed Woodpeckers foraged at a much lower height (maximum 15 m) (Figure 2, right) than other woodpecker species. Grey-headed Woodpeckers and Lesser Yellownape chose considerably different foraging heights from other species, while comparing in between-species (Table 5, above diagonal).

Niche overlap

Niche overlap among species was assessed by pooling all measured variables (N = 36). The Grey-headed Woodpecker had the minimum overlap with other species in its overall foraging niche. Larger woodpecker species, particularly the Grey-headed and Scaly-bellied Woodpeckers, generally showed lower overlap in their selection of foraging tree diameter than

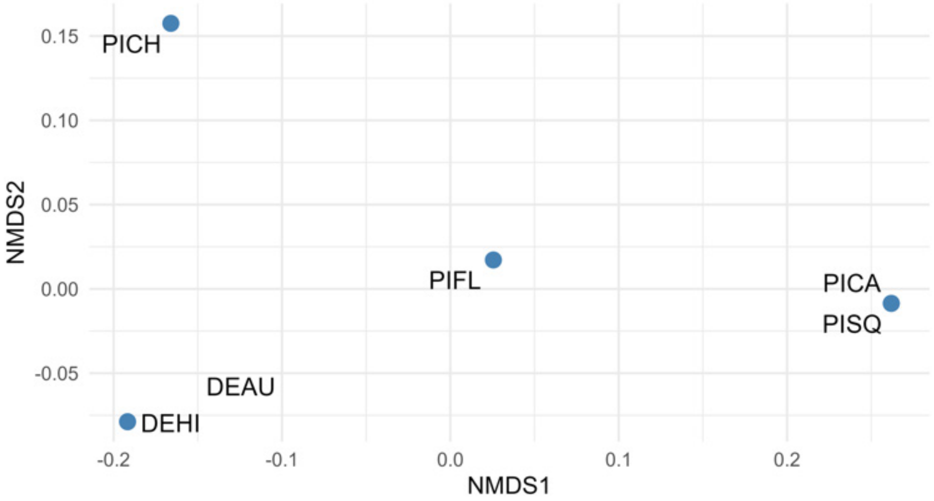

Figure 4. NMDS ordination of average foraging niche dimensions of six woodpecker species. Refer Table 1 for species codes.

Table 5. Summary of post-hoc Dunn's test for differences between species pairs in foraging height (above diagonal) and forage tree diameter (below diagonal). The table shows the p-value with Bonferroni corrections for multiple comparisons. Significant differences were at α = 0.05. Refer Table 1 for species codes.

	DEAU	DEHI	PICA	PISQ	PIFL	PICH
DEAU		**<0.001**	**<0.001**	1.000	**0.013**	**0.028**
DEHI	1.000		**<0.001**	1.000	**<0.001**	**<0.001**
PICA	**<0.001**	**0.048**		**0.011**	**<0.001**	**<0.001**
PISQ	1.000	1.000	1.000		1.000	0.264
PIFL	**<0.001**	**0.016**	1.000	1.000		1.000
PICH	1.000	1.000	1.000	1.000	1.000	

the smaller species. Foraging height appeared to be a key distinguishing factor among woodpecker species, as overlap values for this dimension were often low. Most other species showed moderate overlap with Brown-fronted Woodpeckers and Lesser Yellownape regarding their vertical position (strata). High overlap values in a habitat type and canopy cover suggested limited species segregation along these dimensions. Foraging niche similarities between Grey-headed and Scaly-bellied Woodpeckers were highest (0.94 overlap), whereas the minimum niche overlap was found between Grey-headed Woodpecker and Lesser Yellownape (0.57 overlap) (Table 6).

The Lesser Yellownape demonstrated the most distinct foraging niches within the community by having significantly less overlap with other species. Similarly, the Greater Yellownape also showed comparatively less overlap with other woodpecker species. However, moderately high overlaps were found between the Grey-headed and Scaly-bellied Woodpeckers, as well as between the Brown-fronted and the Himalayan Woodpecker (Figure 3).

NMDS ordination plot revealed clear separation in foraging niches among six woodpecker species (Figure 4). Species such as Grey-headed and Scaly-bellied Woodpeckers clustered closely and showed similar foraging strategies. The Himalayan Woodpecker also showed similar foraging niches, while Lesser Yellownape occupied a more distinct position on the ordination plot, indicating distinct niche segregation.

Relationship between woodpecker morphology and foraging variables

There was a significant correlation ($r = 0.84$, $p < 0.03$) found between the body weights of woodpecker species and the mean DBH of trees used for foraging (Figure 5). No significant relationship was found between the mean foraging height of trees used by woodpecker species and their body weight.

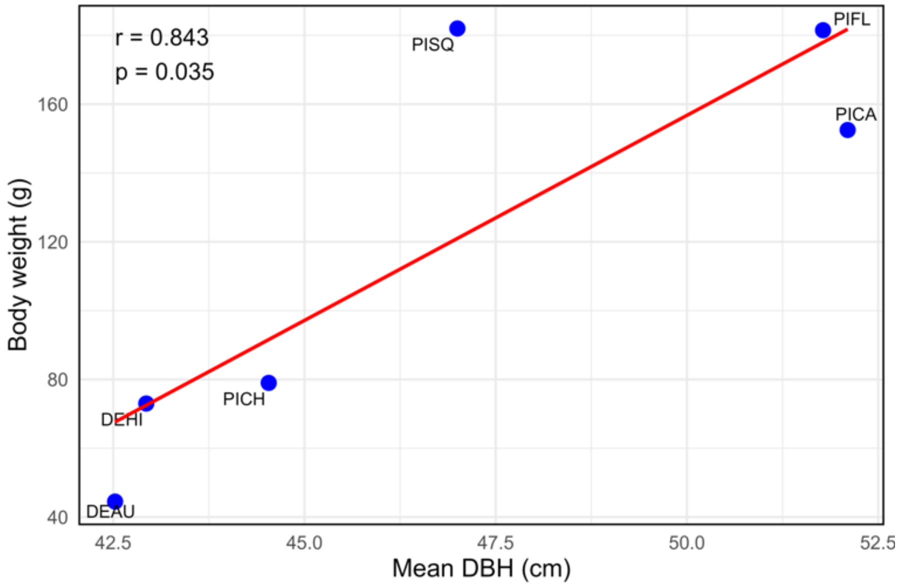

Figure 5. Relationship between Mean DBH and Body weight of six woodpecker species. Refer Table 1 for species codes.

Table 6. Species pair-wise comparison of overall Pianka's niche overlap (N = 36, represents all measured foraging variables pooled together). Refer Table 1 for species codes.

	DEAU	DEHI	PICA	PISQ	PIFL	PICH
DEAU		0.92	0.61	0.70	0.88	0.71
DEHI			0.64	0.71	0.89	0.77
PICA				0.94	0.64	0.57
PISQ					0.71	0.63
PIFL						0.89
PICH						

DISCUSSION

The observations indicate that foraging behaviour and tree attributes significantly differed among woodpecker species. They distinguish their foraging niches from each other by having different vertical positioning and varying preferences for substrates. Other investigations have shown that picids exhibit selectivity in the diameter of foraging trees. The Lesser Spotted Woodpecker *Dryobates minor* in Italy chose trees with smaller diameters than the Great Spotted Woodpecker *Dendrocopos major* (Laiolo et al. 2003). The Downy Woodpecker *Dryobates pubescens* in north America foraged on smaller diameter substrates (Conner et al. 1994), while the Middle-spotted Woodpecker *Dendrocoptes medius* in northern Switzerland (Pasinelli & Hegelbach 1997; Robles et al. 2007), and the Pileated Woodpecker *Dryocopus pileatus* in east-central Louisiana (Newell et al. 2009) had a preference for larger trees.

The woodpecker community in the Western Ghats shows a preference for large-diameter trees, establishing the fundamental relationship between woodpecker body size and resource use (Santharam 1995). These patterns were confirmed among ten sub-Himalayan woodpecker species, reinforcing the relationship between body size and tree diameter preference (Kumar et al. 2020), while Pradhan et al. (2025) demonstrated similar body size-tree diameter relationships across elevation gradients in eastern Himalayan forests.

Similarly, research conducted in the Americas revealed that Red-cockaded Woodpecker(*Dryobates borealis* (Engstrom & Sanders 1997), Magellanic Woodpecker *Campephilus magellanicus* (Vergara & Schlatter 2004), and American Three-toed Woodpecker *Picoides dorsalis* (Gagne et al. 2007) significantly utilized larger trees with their availability. The idea that larger species will use resources more effectively is predicted by optimal foraging theory (Campbell 1987), and this understanding has been supported by these investigations as well as the current study.

Body size influenced the selection of tree size for foraging by woodpeckers, and this pattern could possibly reflect their biochemical capabilities and limitations, which are functions of body mass (Kumar et al. 2020). Foraging height did not exhibit any size-related patterns (Lammertink 2007). Despite being a large species, the Greater Yellownape foraged higher than other species, much like the medium-sized Lesser Yellownape.

The foraging height and vertical position were crucial in differentiating woodpeckers in the current study. The vertical position was somewhat associated with segregation along foraging height. Similarly, segregating woodpecker species based on foraging height was crucial in North America (Williams 1975; Conner et al. 1994), Southeast Asia (Short 1978; Styring & Zakaria 2004; Lammertink 2007), and Europe (Török 1990; Böhm & Kalko 2009). Vertical stratification was identified as a key mechanism enabling coexistence among sub-Himalayan woodpeckers (Kumar et al. 2020), while Pradhan et al. (2025) documented species-specific foraging height preferences that varied across tropical, subtropical, and temperate forest zones in the eastern Himalaya.

Recent comparative studies have further expanded our understanding of these patterns. It has been observed by Si et al. (2023) in northeastern China that vertical stratification in foraging positions is a key factor in segregating foraging among woodpecker species, suggesting that woodpeckers find and occupy specific niches within forests to avoid resource-based competition. This finding is consistent with patterns observed in various Indian studies, suggesting that vertical niche partitioning serves as a widespread mechanism facilitating woodpecker coexistence.

In terms of substrate condition preferences, the findings of this study are consistent with other investigations (Santharam 1995; Kumar et al. 2020; Pradhan et al. 2025), who similarly discovered no interspecific variations in the utilization of substrate conditions for foraging in the Western Ghats, sub-Himalayan and eastern Himalayan woodpecker communities, respectively. Deadwood has been recognized as an essential resource for numerous woodpecker species (Winkler et al. 1995). Nonetheless, since this study found no distinct differences across species regarding substrate conditions, dead substrates may thus be uniformly crucial to all species. In non-protected forests, anthropogenic removal of snags for firewood (Pradhan et al. 2025) may limit this resource, thereby emphasizing the importance of deadwood conservation for maintaining foraging niches. Pradhan et al. (2025) discovered that woodpeckers were more frequently observed foraging on live trees than on snags/dead trees, which is consistent with the findings of this study regarding tree condition preferences. Across all forest types, woodpeckers showed a strong preference for snags and unhealthy trees, which highlights the significance of snags and deadwood for woodpecker foraging (Winkler et al. 1995; Smith 2007; Kumar et al. 2020; Si et al. 2023). This may be attributed to the relatively limited availability of snags in our study area. It has been documented that the snags are commonly used as firewood in non-protected forests, and local communities frequently remove them (Pradhan et al. 2023).

This study shows that the woodpecker species that overlap in one foraging niche dimension may often segregate along multiple other ecological dimensions. Also, the results suggest that niche segregation plays a key role in the stable coexistence of woodpecker species at Ranikhet, Kumaon Himalaya, Uttarakhand. This finding is also consistent with the broader framework established by research findings on the Indian woodpecker community, such as Santharam (1995), who first described multi-dimensional niche partitioning in woodpeckers in the Western Ghats, Kumar et al. (2020) in north-western forests of the Himalaya, and Pradhan et al. (2025) across elevation gradients in the eastern Himalaya.

The availability of resources, such as dietary preferences, roost and nest sites, or interactions with other species, may be key factors for this segregation. Further data collection is required to understand these mechanisms and direct conservation efforts to maintain woodpecker diversity and forest structure, including snag/deadwood and trees of different diameters.

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