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Ecology of Rufous-bellied Woodpecker *Dendrocopos hyperythrus* in Himalayan oak forests

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The Rufous-bellied Woodpecker *Dendrocopos hyperythrus* is the only known sapsucking species occurring in Asia, found in moist temperate broadleaved forests of the Western Himalaya, a forest type threatened by degradation and conversion to other land uses. We studied the habitat selection of the species using point counts over 210 survey-hours in four field seasons between 2016–2018. Field measurement of forest structural variables, analysis of landscape composition and observations on foraging behaviour were carried out to ascertain the reasons for its habitat choice. The species showed a significant preference for dense oak forest over other forest types and land-use. Its occupancy of forest sites was strongly dependent on canopy cover, and showed a weak association with tree girth and the proportion of dense forest in the surrounding landscape. It forages primarily in the mid-storey of the forest, on medium and large trees, mainly on their trunks. Sap-wells created by the woodpecker were seen on nine tree species, and it was seen foraging on seven others. Based on its unique sapsucking behaviour, habitat selection and narrow altitudinal range (1,500–2,700 m), we suggest that the species may be a useful indicator of high-quality oak forest in the Himalaya. Given the prevailing high threat levels to its habitat we urge a review of the IUCN conservation status of the species.

INTRODUCTION

The Rufous-bellied Woodpecker *Dendrocopos hyperythrus* is a medium-sized woodpecker resident in the Himalaya of Pakistan, India, Bhutan and Nepal and the hilly tracts of Bangladesh, Myanmar, Thailand, south-east China and Vietnam, but with a migratory subspecies *subrufinus* breeding in Far East Russia and adjacent north-east China and wintering in southern China (Winkler *et al.* 1995, del Hoyo & Collar 2014). Observations in South Asia indicate that it is a forest specialist largely restricted to moist temperate broadleaved forest between 1,500 and 2,800 m (Osmaston 1916, Grimmett *et al.* 1998, Dixit *et al.* 2016, eBird 2018).

The Rufous-bellied Woodpecker is the only species of 'sapsucking' woodpecker in Asia, feeding on sap from holes that it drills in the cambium of trees (referred to as 'sap-wells'). In this respect, it is similar to the four species of *Sphyrapicus* sapsucker found in North America. The Rufous-bellied Woodpecker shows the anatomical adaptations for sapsucking, including a more slender pointed bill for drilling into cambium (relative to other woodpecker species of its size) and brush-like tip to its tongue for licking tree sap (Osmaston 1916, Abdulali 1968, Zusi & Marshall 1970).

The species is listed as of Least Concern (BirdLife International 2018a), but it is believed that the overall population trend is adverse, with a decline in numbers probably caused by forest degradation and conversion, but there is currently sparse information to support such speculation. The species is little studied; early observations were by Osmaston (1916) and Abdulali (1968), and the last field observations were published from forests in Thailand by Zusi & Marshall (1970). Distributional records from the Western Himalaya have been posted on eBird (eBird 2018) and in Dixit *et al.* (2016), but there is no other data. A detailed study of this species, including its responses to forest degradation and conversion, its relationship with forest structure, and foraging ecology, is long overdue.

Sphyrapicus sapsucker species probably play a key role in broadleaved forests because their sap-wells are available to other avian and mammal species for foraging (e.g. Daily *et al.* 1993). It has also been found that the number of tree cavities created by sapsuckers is an order of magnitude greater than those made by other woodpeckers, thereby increasing the nesting holes available to secondary cavity-nesters (Daily *et al.* 1993). If this is true of the Rufous-bellied Woodpecker, it may well be an ecologically important species in its Himalayan habitat and an umbrella species for forest conservation.

In 2016, intensive surveys of moist temperate broadleaved forests between 1,700 and 2,400 m in the Western Himalaya yielded numerous sightings of Rufous-bellied Woodpecker (Shahabuddin *et al.* 2017). Such forests occur mainly between 1,500 and 3,000 m and are, in most places, dominated by oak species such as banj *Quercus leucotrichophora*, tilonj *Q. floribunda* and kharsu *Q. semecarpifolia* (hereafter referred to as 'oak forest'—see Singh & Singh 1987). However, forest degradation and loss, caused by over-exploitation, warming, tourism activities, road-building and pine invasion, may threaten the species's habitat (Pandit *et al.* 2007, authors' pers. obs.). Woodpecker species have been adversely affected by forest modification in European broadleaved forests (see Angelstam & Mikusinski 1994, Roberge *et al.* 2008, Stachura-Skierczynska *et al.* 2009). There is thus an urgent need for systematic studies of the ecology of the Rufous-bellied Woodpecker in the Western Himalaya, as it may be vulnerable to the effects of anthropogenic changes.

Our specific objectives were: (a) to study the habitat selection of the Rufous-bellied Woodpecker in the Western Himalaya; (b) to study the role of forest vegetation structure in its habitat selection; and (c) to explore its microhabitat preferences, with respect to tree species utilised, girth class, height of foraging and foraging substrate, in order to understand its dependence on its forest habitat.

METHODS

Study area

A 1,285 km^2 study area, covering parts of the districts of Nainital and Almora in Uttarakhand state, India, was selected for intensive study within the oak forest biome lying between 29.30°N 79.36°E and 29.54°N 79.84°E, in a region which forms part of an Endemic Bird Area (BirdLife International 2018b). Temperatures can reach a low of 2.8°C in January and a high of 26.8°C in June and the average annual rainfall is about 1,500 mm (Climate-data.org 2018). The Rufous-bellied Woodpecker shares this forest habitat with nine other primary cavity-nesters, the smallest being the Speckled Piculet *Picumnus innominatus* and the largest the Greater Yellownape *Chrysophlegma flavinucha* (Shahabuddin *et al.* 2017). The study area was chosen after ground surveys because there was adequate representation of the six primary land-use types in this region: dense oak forest, degraded oak forest, lopped forest (heavily degraded), pine forest, built-up (tourist) sites and cultivation, between 1,700 and 2,400 m. Dense oak forest, degraded and lopped oak forest are well-documented, distinct categories of forest, created by different types of exploitation (see Thadani & Ashton 1995). Dense oak forests, which are largely protected from human use, have thick canopy cover, a preponderance of large and tall trees, dense epiphytes and mosses and a dense understorey of shrubs and saplings. Degraded oak forest, created by light extraction for forest products over long periods, tends to have thinner canopy cover, shorter and younger trees, a poor understorey and largely lacks epiphytes. Lopped forest is heavily degraded and has almost no canopy owing to heavy extraction of fodder and fuelwood, but it possesses a dense shrub layer caused by tree-lopping for fodder. Cultivation consists of fruit orchards mixed with cereal and vegetable farming on terraces created along hill slopes. Pine forest is largely dominated by chir pine *Pinus roxburghii* with a few associates such as kaafal *Myrica esculenta* and rhododendron *Rhododendron arboreum*. Chir pine is native to this region but has considerably expanded its range at the cost of oak forest, owing to the prevalent forest management practices—for example, frequent fires and intense use of oak forests lead to 'invasion' by chir pine, which regenerates well in drier soils and relatively open tree canopy.

In the study landscape, 262 survey sites were selected within the mosaic of forest, cultivation and human settlements. The number of sites was determined by the number that could be effectively sampled in each field season by a single team of observers, as well as by the limited extent of remnant oak forests. Each survey site was a point location having a homogeneous buffer of at least 50 m, and was at least 200 m from the next nearest site. A GPS unit (Garmin Etrex 20) was used to record the location of each site. Within the limited areas of oak forest, the selection of points a minimum of 200 m apart caused unavoidable clustering of survey points at the landscape scale, which may have led to non-independence of data. A Moran's I test was therefore carried out, using the residuals of the GLMM model (see below) to check for spatial autocorrelation (R Development Core Team 2014). The Moran's I coefficient was -0.0018 (with $p<0.53$), indicating lack of autocorrelation in bird abundance amongst the survey sites.

The sites surveyed changed slightly in each field season, resulting in four separate datasets hereafter identified by season and year (Table 1). In summer 2016, 23 sites were surveyed in each of the six primary land use categories in the Mukhteshwar and Maheshkhan areas, a total of 138 survey sites. In summer 2017, a set of 60 additional sites were surveyed in the Pangot area, distributed equally across the six land use categories. In winter 2017 and summer 2018, only dense and degraded forest sites (37 of each) were surveyed in the Mukhteshwar and Maheshkhan areas; 30% of these sites were common to those surveyed in summer 2016. March to May (summer season) is the peak breeding season for most bird species, while many species undertake altitudinal migrations in winter (November to February).

Data collection

At each site the presence of Rufous-bellied Woodpecker was confirmed by two observers using the point count method. The same pair of observers surveyed the sites throughout each field season, thus eliminating observer bias. At each site the observers scanned the forest vegetation within a radius of 30 m for 15 minutes. Since Rufous-bellied Woodpecker is a conspicuously coloured species which forages actively (Plate 1), it was easily found if present in the area. Additionally, if calls were heard, an attempt was made to locate the bird to confirm that it was within the circumscribed survey area. Surveys were repeated two or three times in each field season. Surveys started at 07h00 and continued until 10h00, to match the observed period of maximum bird activity in the forest.

In summer 2016 and summer 2017 we carried out surveys in all six land-use types for Rufous-bellied Woodpecker; these surveys were repeated twice during each field season. No data were collected on vegetation structure or foraging behaviour. In both winter 2017 and summer 2018, surveys were repeated three times at the same 37 dense oak forest and 37 degraded oak forest sites only and in addition data were collected on vegetation structure and foraging behaviour. Data from each of the four field seasons were analysed separately.

To study foraging behaviour, the following notes were taken whenever the woodpecker was recorded: the tree species and DBH (diameter at breast height in cm), the foraging height (metres) and the foraging substrate (main trunk, primary branch, secondary branch, branch tips, snags or forest floor). In addition, sightings of the species away from the survey sites were also recorded, and similar data taken. Images were taken of all the sap-trees found for later identification.

To characterise vegetation structure, three 100 m^2 circular plots (radius 5.64 m) were established within the 30 m radius of each survey site. The sub-plot size was chosen following Thadani & Ashton (1995), who found it an efficient way to collect vegetation data in topographically variable terrain. Each of the three plots was 15 m from the centre of the point count site and at an angle of about 120° from each other. Within each plot, vegetation structural variables that are known to influence bird nesting and foraging were measured: canopy height, tree DBH, tree density, canopy cover, understorey density and vertical stratification. These values were averaged across the three plots within each survey site (see Kumar & Shahabuddin 2006, Jayapal *et al*. 2009). All trees with a DBH greater than 10 cm were counted and identified and their DBH recorded. Tree density was estimated as the number of trees in the three sub-plots. The DBH data were used to obtain values of mean tree DBH for each plot. Canopy cover was measured at the centre of each plot, using a canopy densitometer. One reading was taken in each of the four cardinal directions and these were then averaged to get a reading for canopy cover per plot. The height of the tallest tree in each sub-plot was averaged across the three plots

Table 1. **Summary and results of four field season surveys showing habitat usage and encounter rates of Rufous-bellied Woodpecker *Dendrocopos hyperythrus*.**

Field season	No. of survey sites	Land use categories (number of sites)	No. of visits per site	No. of survey hours	No. of records of Rufous-bellied Woodpecker	Land uses in which recorded	Encounter rate per hour in forest	No. and % of sites where recorded
Summer (April–June 2016)	138	dense oak (23), degraded oak (23), lopped oak (23), orchards (23), pine forest (23), built-up sites (23)	2	69	17	dense oak, degraded oak	0.5	10 (21.7%)
Summer (May 2017)	60	dense oak (10), degraded oak (10), lopped oak (10), orchards (10), pine forest (10), built-up sites (10)	2	30	16	dense oak, degraded oak	1.07	12 (60%)
Winter (November 2017–January 2018)	74	dense oak (37), degraded oak (37)	3	55.5	17	dense oak, degraded oak	0.31	13 (17.6%)
Summer (February–April 2018)	74	dense oak (37), degraded oak (37)	3	55.5	21	dense oak, degraded oak	0.38	12 (16.2%)

to obtain the average canopy height per site. Understorey density was estimated within a circular sub-plot of 10 m^2 (radius 1.77 m) located within each of the three sub-plots and defined as the total number of stems of saplings, shrubs and bushes that had a minimum height of 0.5 m and DBH <10 cm. Understorey density was estimated in two categories: stems <1.5 m in height and those >1.5 m in height. Vertical stratification was calculated as a diversity index based on the presence or absence of vegetation at different height intervals in metres (0–1, 1–2, 2–3, 3–4, 4–6, 6–8, 8–12, 12–16 and >16 m) directly above and within a 50 cm radius of a given point. Measures of vertical stratification were made in 12 locations per site (four per plot). Average values of the vegetation structural variables in dense oak forest and degraded oak forest along with the values of the t-tests (for testing differences) and the associated p-values are given in Figure 1. Dense oak forest had significantly higher values for all the vegetation variables measured, apart from tree density. This suggests that, on average, degraded forest had similar numbers of trees but of smaller DBH, as was expected from visual surveys.

Since bird abundance can also depend on the proximity of forests in the wider landscape, we analysed land use using Multispectral Landsat 8 satellite imagery. For this, supervised classification using the Spectral-Angle Mapper algorithm was carried out using the Semi-Automatic Classification Plugin (SCP) in Quantum GIS version 2.18.1. A total of 295 ground control points (GCP) were collected from across the study site using a Garmin Etrex 20 GPS. The land-cover classification resulted in an overall accuracy of 82% with a Kappa hat value of 0.77 which can be considered satisfactory for the purposes of this study (Foody 2008). Classification of dense oak forests had a producer accuracy of 95%, a user accuracy of 86% and Kappa hat of 0.79. From this land-use map, the proportion of dense forest occurring within a 500 m radius of each survey point was calculated.

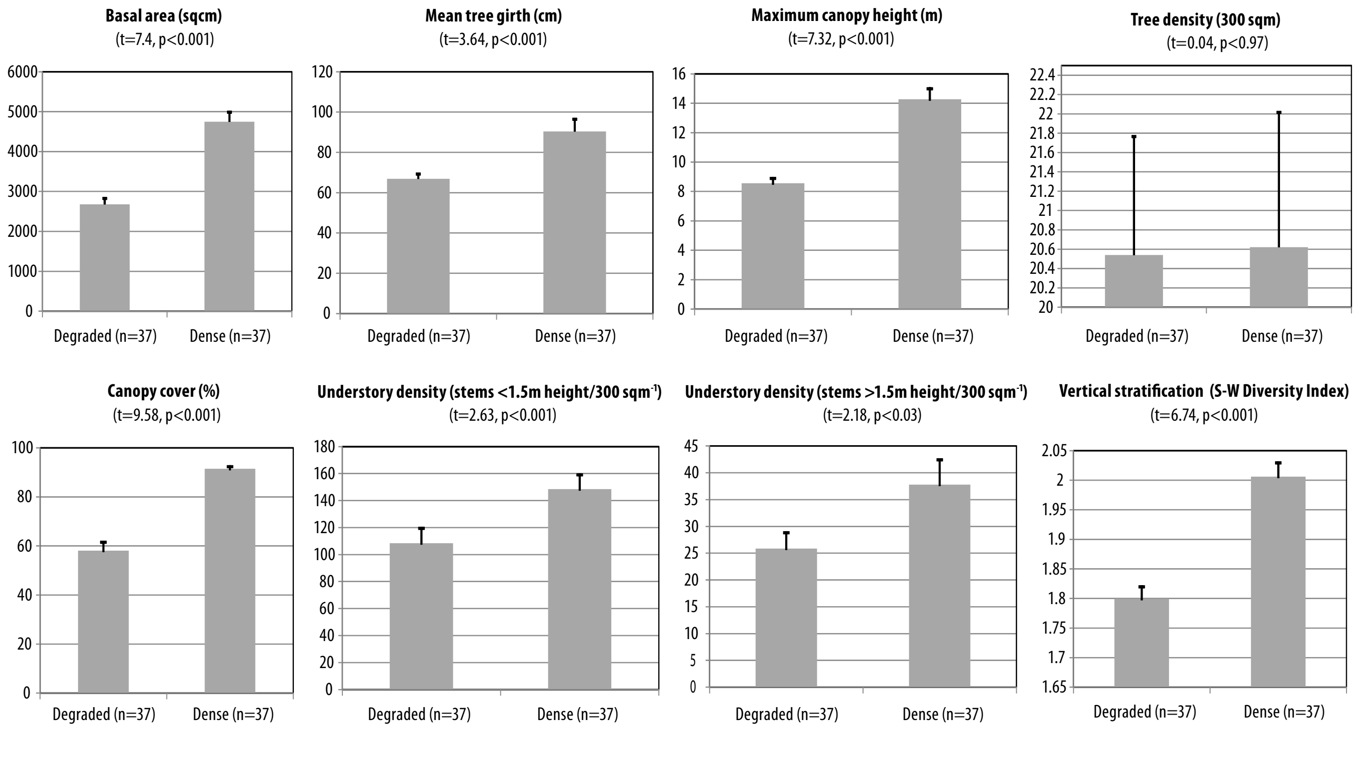
Data analysis

In order to study the habitat selection of Rufous-bellied Woodpecker, Indicator Species Analysis (ISA) was carried out using each of the four field season datasets separately. ISA is a randomisation technique used to assess the value of different species for indicating specific environmental conditions, thereby exploring preference for a given habitat (McCune & Mefford 1999). Based on concepts of abundance and frequency, ISA combines both 'fidelity' (degree of faithfulness of a species to a particular habitat) and 'exclusivity' (degree to which a species occurs exclusively in a given habitat) of a species to a group of sites. ISA was carried out using the software PC-Ord (McCune & Grace 2002). We used p-values of 0.05 and below to indicate significance of indicator status. Strength of indication value (IV) of a given species for a given habitat was classified as strong (IV 70–100%), moderate (IV 40–69%) or weak (IV <40%).

Generalised Linear Mixed Models (GLMM—see Bolker *et al*. 2009) were used to evaluate the combined influence of various vegetation variables and landscape forest (co-variates or predictors) on the presence/absence of Rufous-bellied Woodpeckers (dependent variable). GLMMs are known as such due to their ability simultaneously to quantify fixed effects of predictors as well as random effects caused by temporal variation or uneven detection. GLMMs are also suited for modelling count data that are non-normally distributed (Bolker *et al*. 2009). We therefore modelled the vegetation and landscape co-variates as fixed effects and presence/absence in six successive surveys (winter 2017 and summer 2018) as random effects. Corrected Akaike Information Criterion (AICc; corrected for small sample size) was used to rank the most parsimonious model, and the one with the lowest AICc was taken as the best fitted model. To evaluate the predictive value of the fitted models, we calculated marginal R^2 (variance explained only by the fixed effects) and conditional R^2 (variance explained by the entire model) values using the method described by Nakagawa & Schielzeth (2013). All modelling was carried out in R 3.5.0 (R Development Core Team 2014).

Foraging behaviour of Rufous-bellied Woodpecker with respect to choice of tree species, DBH class, foraging height and foraging substrate was explored by plotting the data showing frequency of bird observations against the data range of the given habitat variable. Since the survey sites were the same, data from winter 2017 and

Figure 1. Comparison of vegetation structural variables between dense oak forest and degraded oak forest. Results of the t-tests for difference of means between the two habitats are also given.



summer 2018 were combined for this analysis, to obtain a larger sample size and hence a fifth dataset (Table 2).

RESULTS

Natural history

During the study, which involved 210 survey-hours over four field seasons, we observed the species 71 times (Table 1). Rufous-bellied Woodpeckers were usually seen alone (similar numbers of males and females) or in pairs. Birds were often seen on the same trees on consecutive visits, suggesting a high degree of site fidelity. Encounter rates in forest (dense and degraded combined) varied from 0.31/hr to 1.07/hr of survey time (Table 1). The species was sighted in 16–60% of the forest sites (dense and degraded combined) in any given field season (Table 1).

The woodpeckers were often seen making or feeding from sap-wells in addition to insect-gleaning. It was not always possible to distinguish drilling or sap-feeding from insect-feeding; also, birds may glean insects from holes made earlier.

Habitat selection

All 71 observations were from dense oak forest or degraded oak forest; there were no sightings in any other land use type. Several opportunistic sightings of Rufous-bellied Woodpecker were all made in dense forest and degraded forest.

ISA suggested that the Rufous-bellied Woodpecker showed a significant preference ($p<0.001$) for dense oak forest over all other land uses in all four field seasons (Table 2). However, the indication value was variable, ranging from a low of 34.5% in summer 2016 (weak indication value) to a high of 87.5% in summer 2017 (strong indication value). Winter 2017 and summer 2018 data also showed relatively low indication values but the combined winter 2017–summer 2018 showed a moderate indication value of 59.1%.

Role of forest vegetation structure

The GLMM analysis showed that the best model contained the variables canopy cover, mean tree DBH and forest proportion. Coefficients of this model indicated that Rufous-bellied Woodpecker occupancy was strongly dependent on canopy cover ($\beta = 1.60$, $p<0.02$), and weakly dependent on mean tree DBH ($\beta = 0.26$, $p<0.17$) and forest proportion ($\beta = 0.33$, $p<0.21$). The final model for Rufous-bellied Woodpecker occupancy showed a marginal R^2 of 0.24, so the three retained co-variates explained 24% of the variation in occurrence of the species. Further, the variability in bird detection (random effects) contributed almost as much variability to the model as the co-variates, as indicated by the conditional R^2 (0.43).

Microhabitat utilisation

Rufous-bellied Woodpecker was seen foraging on seven species of tree, with sightings confirmed on banj oak (35), tilonj oak (18), kaafal (4), chir pine (2) and rhododendron, *Lyonia ovalifolia* and utis *Alnus nepalensis* (1 each). In addition, sap-wells made by the species were seen commonly on tilonj trees and less frequently on five other forest species: rhododendron, maple *Acer* spp., cedar *Cedrus deodara*, chir pine and kaafal. These trees had the characteristic pattern of sap-wells that were 1–2 cm apart and drilled in linear fashion, often girdling the entire girth of a tree. In many cases, the entire height of the tree-trunk was covered with successive lines of sap-wells (Plate 2). Surprisingly, no sap-wells were seen on banj oak, which is the commonest tree species in the forest type studied. Three other tree species—toon *Toona ciliata*, cypress *Cupressus torulosa* and *Ficus* spp.—harboured sap-wells; these species are native to the Himalaya but were planted within our study altitude range in orchards adjacent to forests.

Figure 2 shows that trees of DBH 16–65 cm were used disproportionately for foraging purposes. Close to 90% of all observations of Rufous-bellied Woodpecker were on the main tree-trunk and the remainder on primary branches, whilst it was never seen foraging on secondary branches, branch tips, snags or the ground. Most sightings of foraging birds were 3–10 m above the ground, with very few sightings below 3 m, characteristic of a mid-storey species (Figure 3).

DISCUSSION

Our study suggests that, in our study area at least, the Rufous-bellied Woodpecker is a habitat specialist that prefers dense oak forests and therefore is not a species that can survive in degraded or lopped oak forest, pine forest or fruit orchards, as shown by our ISA. In this respect, this species is similar to other habitat specialists in the family Picidae that prefer old-growth forest, such as the Great Slaty Woodpecker *Mulleripicus pulverulentus* in subtropical dipterocarp forests (Kumar *et al.* 2011) and White-bellied Woodpecker *Dryocopus javensis* in the tropical wet forests of the Western Ghats, south-west India (Santharam 2003). The results of the GLMM showed the effects of canopy cover, average tree DBH and forest proportion on the occupancy of the species. These three factors are indicative of high-quality unfragmented forest and have been found to be determinants of woodpecker occurrence in the forests of the lower Himalaya and in other areas such as Borneo (Lammertink *et al.* 2009, Kumar *et al.* 2014). However, the predictive value of our occupancy model was relatively low, as seen in the low R^2 values. More data, collected from a larger study area, are required to explore these patterns further.

Foraging behaviour and the resultant patterns of forest utilisation by the Rufous-bellied Woodpecker also point to its preference for late-successional oak forest in the study area, suggesting that the species is largely a mid-storey forager, preferring to feed on trunks of mid-sized and large trees, particularly banj and tilonj oaks. Foraging could be restricted to tree-trunks due to the need for tree-sap as a nutritive source. However, insufficient data prevented these foraging preferences from being tested quantitatively using resource selection indices.

The species was seen foraging on seven tree species and sap-wells were found on nine species; florally diverse forest may therefore be important for it. This aspect of its ecology also needs further study: forest degradation due to intensive use results in floral impoverishment of oak forests at this altitude and may adversely affect its occurrence (Shahabuddin & Thadani 2018).

Table 2. Indicator value of Rufous-bellied Woodpecker for various forest types based on Indicator Species Analysis.

Dataset	No. of sightings	Indication value	P-value	Preferred land use
Summer 2016	17	34.50%	0.001	dense oak forest
Summer 2017	16	87.50%	0.001	dense oak forest
Winter 2017	17	34.60%	0.001	dense oak forest
Summer 2018	21	37.20%	0.001	dense oak forest
Winter 2017+Summer 2018	38	59.10%	0.001	dense oak forest


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Plate 1. Rufous-bellied Woodpecker *Dendrocopos hyperythrus* in its oak forest habitat, Mukhteshwar, Uttarakhand, India, 29 April 2018.

There are other aspects of the ecology of the Rufous-bellied Woodpecker that suggest its vulnerability to the degradation of its oak forest habitat. The available literature indicates that the species is probably restricted to oak forest habitat within a narrow altitudinal range (1,500–2,800 m). This inference is borne out by several other distributional studies in the Western Himalaya. Systematic long-term surveys in six sites at 1,500–3,800 m found this species between 1,500 and 2,600 m, but not above (Dixit *et al*. 2016). Osmaston (1916) also wrote that the best habitat for Rufous-bellied Woodpeckers was at 1,900–2,300 m, based on observations of sap-trees. eBird data confirm that there have been very few sightings below 1,700 m and above 2,700 m in the Western Himalaya. We have made three sightings below 1,700 m in the Western Himalaya, but these were in unusually low oak-dominated forests at 1,400–1,500 m. There are no records from subtropical broadleaved forests, which occur at 300–1,000 m in the Western Himalaya.

Furthermore, the species appears to be a year-round resident of oak forest in this altitudinal zone (1,700–2,400 m), which could increase its vulnerability to habitat change. Absence of altitudinal migration is suggested by similar encounter rates in summer 2018 (0.38/hr) and winter 2017 (0.31/hr; Table 1). It is possible that birds migrating downhill in winter may be replaced by individuals from higher reaches, resulting in similar encounter rates in the two seasons, but the chances of this are low given the scarce observations of the species beyond the altitudinal range of 1,500–2,800 m, either in winter or in summer. Moreover, the upper limit of broadleaved forests (to which sapsuckers are known to be bound) ranges from 2,800–3,000 m in the Himalaya (Singh & Singh 1987).

Indicator species are typically those whose occurrence can be used to identify certain environmental conditions or whose protection is

Plate 2. Toon tree *Toona ciliata* showing grid of sap-wells on its trunk, in Mukhteshwar area, Uttarakhand, India, 25 March 2018.


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concomitant with that of a large proportion of coexisting species in its forest habitat (Caro & O'Doherty 1999). As they are highly selective in their nesting and foraging habits, woodpeckers appear to serve well as indicator species for forest quality (Angelstam & Mikusinski 1994). Earlier woodpecker surveys have been used for monitoring forest quality owing to the sensitivity of the species to forest modification and to their ease of location, particularly in sites extracted for timber (Drever *et al.* 2008).

As a possible indicator species, the Rufous-bellied Woodpecker appears to be ideal, as it is conspicuously coloured, moderately common in its preferred habitat, has a long generation time and is vulnerable to forest degradation (Caro & O'Doherty 1999). While encounter rates in forest are relatively low, they can be increased by using call playback in dense forest habitats, as shown by Kumar & Singh (2010) for woodpecker species. The increased encounter rate would make it easy to locate Rufous-bellied Woodpeckers in time-bound landscape surveys. Other data from our study area indicate that the α-diversity of birds was significantly higher in sites where this species was present in comparison to those where it was not, suggesting spatial correlation with biodiverse forest stands (T. Menon, unpublished data). More research is required on the question of it being an indicator or umbrella species, but on present evidence the species seems likely to serve one or both roles well.

With the advance of infrastructure development such as highways, dams, tourist resorts and the concomitant influence of forest over-exploitation in the mid-altitudinal Himalaya, the preferred habitat of the Rufous-bellied Woodpecker is likely to shrink further. The extent of dense oak forest is already limited in comparison to pine forest and other land uses. Although it occurs over a large geographic area, within the Himalaya the species could be restricted to protected oak forest occurring in a narrow altitudinal range. Its vulnerability may be further increased by climate change. Further field surveys and status assessments of both this specialist woodpecker and its remnant oak forest habitat in the Himalayan region are a priority. Currently the species is listed as of Least Concern (BirdLife International 2018a) but given the proximate threats to its habitat, and its specialised ecology, it is believed that the overall population trend is adverse and we urge an early review of its status.

Figure 2. Frequency of Rufous-bellied Woodpecker sightings on trees of various DBH classes.

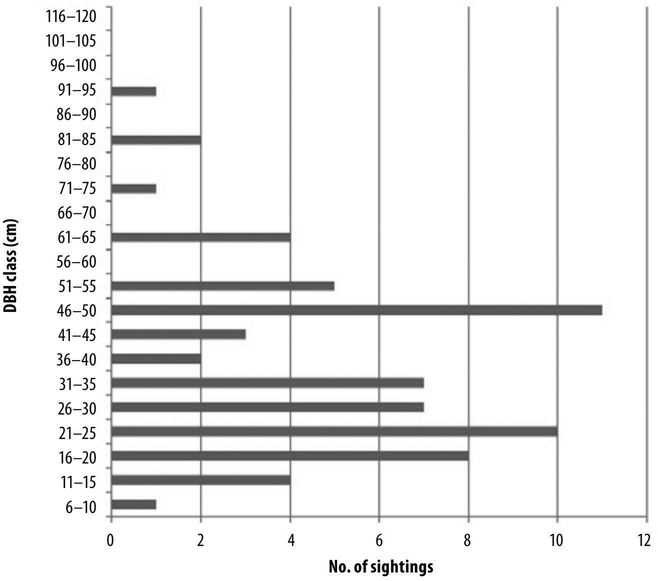
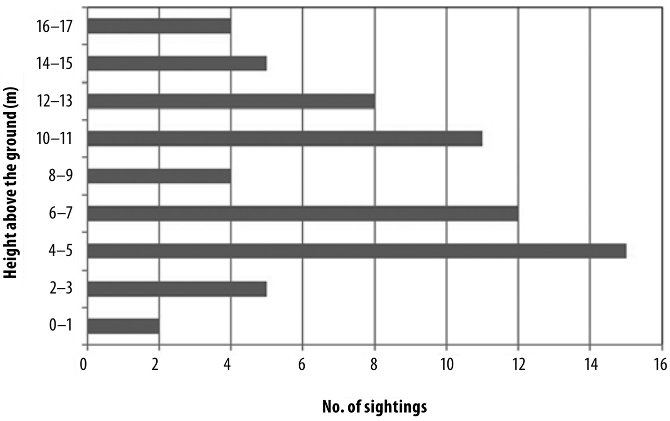


Figure 3. Distribution of Rufous-bellied Woodpecker sightings along the height gradient.



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References

Abdulali, H. (1968) Sap sucking by Indian woodpeckers. *J. Bombay Nat. Hist. Soc.* 65: 219–221.

Angelstam, P. & Mikusinski, G. (1994) Woodpecker assemblages in natural and managed boreal and hemiboreal forest—a review. *Ann. Zool. Fennici* 31: 157–172.

BirdLife International (2018a) Species factsheet: *Dendrocopos hyperythrus*. Accessed at http://www.birdlife.org on 01/10/2018.

BirdLife International (2018b) Endemic Bird Area factsheet: Western Himalayas. Accessed at http://www.birdlife.org on 01/10/2018.

Bolker, B. M., Brooks, M. E., Clark, C. J., Geange, S. W., Poulsen, J. R., Stevens, M. H. & White, J. S. (2008) Generalized linear mixed models: a practical guide for ecology and evolution. *Trends Ecol. Evol.* 24: 127–135.

Caro, T. M. & O'Doherty, G. (1999) On the use of surrogate species in conservation biology. *Conserv. Biol.* 13: 805–814.

Climate-data.org (2018) Accessed at https//en.climate-data.org/asia/india/uttarakhand/nainital-33829.

Daily, G. C., Ehrlich, P. R. & Haddad, N. M. (1993) Double keystone bird in a keystone species complex. *Proc. Nat. Acad. Sci.* 90: 592–594.

Dixit, S., Joshi, V. & Barve, S. (2016) Bird diversity of the Amrutganga Valley, Kedarnath, Uttarakhand, India with an emphasis on elevational distribution of species. *Check List* 12(2): 1874. DOI: http://dx.doi.org/10.15560/12.2.1874 ISSN 1809-127X.

Drever, M. C., Aitken, K. E. H., Norris, A. R. & Martin, K. (2008) Woodpeckers as reliable indicators of bird richness, forest health and harvest. *Biol. Conserv.* 141: 624–634.

eBird (2018) Accessed at http://www.ebird.org.

Foody, G. M. (2008) Harshness in image classification accuracy assessment. *Internatn. J. Remote Sensing* 29: 3137–3158.

Grimmett, R., Inskipp, C. & Inskipp, T. (1998) *Birds of the Indian subcontinent*. Delhi: Oxford University Press.

del Hoyo, J. & Collar, N. J. (2014) *The HBW–BirdLife International illustrated checklist of the birds of the world, 1: non-passerines*. Barcelona: Lynx Edicions.

Jayapal, R., Qureshi, Q. & Chellam, R. (2009) Importance of forest structure, vs. floristics to composition of avian assemblages in tropical deciduous forests of Central Highlands, India. *Forest Ecol. Mgmt.* 257: 2287–2295.

Kumar, R. & Singh, P. (2010) Determining woodpecker diversity in the sub-Himalayan forests of northern India using call playbacks. *J. Field Orn.* 81: 215–222.

Kumar, R. & Shahabuddin, G. (2005) Effects of biomass extraction on vegetation structure, diversity and composition of an Indian tropical dry forest. *Environ. Conserv.* 32(3): 1–12.

Kumar, R., Shahabuddin, G. & Kumar, A. (2011) How good are managed forests at conserving native woodpecker communities? A study in sub-Himalayan dipterocarp forests of northwest India. *Biol. Conserv.* 144: 1876–1884.

Kumar, R., Shahabuddin, G. & Kumar, A. (2014) Habitat determinants of woodpecker abundance and species richness in sub-Himalayan dipterocarp forests of north-west India. *Acta Orn.* 49: 243–254.

Lammertink, M., Prawiradilaga, D. M., Setiorini, U., Naing, T. Z., Duckworth, J. W. & Menken, S. B. J. (2009) Global population decline of the Great Slaty Woodpecker (*Mulleripicus pulverulentus*). *Biol. Conserv.* 142: 166–179.

McCune, B. & Grace, J. B. (2002) *Analysis of ecological communities*. Oregon: MjM Software Design.

McCune, B. & Mefford, M. J. (1999) *PC-Ord-multivariate analysis of ecological data*. V4. Oregon: MjM Software Design.

Nakagawa, S. & Schielzeth, H. (2013) A general and simple method for obtaining R^2 from generalized linear mixed-effects models. *Methods in Ecol. Evol.* 4: 133–142.

Osmaston, A. E. (1916) Curious habits of wood-peckers in the Kumaon hills. *J. Bombay Nat. Hist. Soc.* 24: 363–366.

Pandit, M. K., Sodhi, N. S., Koh, L. P., Bhaskar, A. & Brook, B. W. (2007) Unreported yet massive deforestation driving loss of endemic biodiversity in Indian Himalaya. *Biodivers. & Conserv.* 16: 153–163.

R Development Core Team (2015) *R: a language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing.

Roberge, J., Mikusinski, G. & Svensson, S. (2008) The white-backed woodpecker: umbrella species for conservation planning. *Biodivers. & Conserv.* 17: 2479–2494.

Santharam, V. (2003) Distribution, ecology and conservation of the White-bellied Woodpecker *Dryocopus javensis* in the Western Ghats, India. *Forktail* 19: 31–38.

Shahabuddin, G. & Thadani, R. (2018) Biodiversity in managed landscapes: a view of potential and constraints in van panchayats of Kumaon Himalayas, India. Pp.109–131 in S. Bhagwat, ed. *Conservation and development in India: reimagining wilderness*. London: Taylor and Francis.

Shahabuddin, G., Goswami, R. & Gupta, M. (2017) An annotated checklist of the birds of banj oak–chir pine forests of Kumaon, Uttarakhand. *Indian Birds* 13(2): 29–36.

Singh, J. S. & Singh, S. P. (1987) Forest vegetation of the Himalaya. *Bot. Rev.* 53: 80–192.

Stachura-Skierczynska, K., Tumiel, T. & Skierczynski, M. (2009) Habitat prediction model for three-toed woodpecker and its implications for the conservation of biologically valuable forests. *Forest Ecol. Mgmt.* 258: 697–703.

Thadani, R. & Ashton, P. M. S. (1995) Regeneration of banj oak (*Quercus leucotrichophora* A. Camus) in the central Himalaya. *Forest Ecol. Mgmt.* 78: 217–224.

Winkler, H., Christie, D. A. & Nurney, D. (1995) *Woodpeckers*. Robertsbridge UK: Pica Press.

Zusi, R. L. & Marshall, J. T. (1970) A comparison of Asiatic and North American sapsuckers. *Nat. Hist. Bull. Siam Soc.* 23: 393–407.

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