

Influence of Habitat Structure and Anthropogenic Disturbances on Diurnal Raptor Community in Rajaji National Park, India



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R·R·C·F

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1. INTRODUCTION

Raptors being apex predators play important roles in structuring and functioning of their ecosystems. They maintain biodiversity (Sergio et al., 2008) by controlling the population of meso-predators (Lourenço et al., 2011; Sergio and Hiraldo, 2008) and by inducing fear of predation which limit foraging and consequently population size of their prey species (Abramsky et al., 2002; Buchanan, 2012). Another important yet underappreciated service provided by selected group raptors is “scavenging”, which not only guarantees flow of nutrients in the food chain but also prevents spread of diseases (Sekercioglu, 2006). Unfortunately, forest interior raptor species, are sensitive to anthropogenic disturbance because of their unique life-history traits, large ranging behavior and specific habitat preference and are hence rapidly declining worldwide. (Carrete et al., 2009; Thiollay, 1993). Apart from habitat loss and persecution, raptors are declining due to degradation of their habitats, especially in the tropical forest (Bildstein et al., 1998; Thiollay, 1992).

Tropical forests in developing countries have the highest diversity of raptors in the world (Bildstein et al., 1998). Simultaneously, more than 60% of the raptors in Indo-malayan and Afro-tropical forests are threatened by one or more threats in their habitat. These two areas are identified as the most disturbed realms of world (Hannah et al., 1994). One of the widespread reason of habitat degradation in such countries, including India, is the long-term extraction of forest biomass (firewood, fodder, timber etc.) by rural population for sustenance and livelihood (Kothari et al., 1989; Thiollay, 2006). Recent studies have established that such activities could significantly alter the habitat structure and composition with gradual modification of faunal communities (Chettri et al., 2002; Sagar et al., 2003; Shahabuddin and Kumar, 2006).

Such disturbances have altered the raptor community composition as well by influencing the constituent species. Thiollay (1993) investigated the response of raptor community to fragmentation and forest degradation in the Western Ghats. He found that certain raptors preferring open habitats such as Common kestrel *Falco tinnunculus* and Black-shouldered kite *Elanus caeruleus* were favored by degradation whereas forest interior species such as Oriental-honey buzzard *Pernis ptilorhynchus* and *Accipiter sp.* decreased in number with increasing degradation. Also, highly degraded areas had the

lowest number of raptor species whereas forest edges and woodlots with high habitat heterogeneity were the richest. Carrette et.al.(2009) investigated the effect of habitat transformation and fragmentation on raptor community in five different Argentinian biomes. In this study, Carrette et.al. (2009) observed that landscape modification resulted in decreases in raptor richness, diversity and abundance. In West-Africa, populations of all raptor species declined severely in habitats outside protected areas was attributed to human population growth and associated disturbance (Thiollay 2006).

Ecological research on raptors in India is still in its nascent stage and basic information on distribution, biology, behavior of even the common most raptors is missing. In order to understand the effect of habitat degradation owing to small-scale biomass extraction on diurnal raptors as well as their habitat use pattern, I proposed this study in one of the important protected areas, the Rajaji National Park (hereafter Rajaji), of northern India. Rajaji in the foothills of Himalaya is an important habitat for 32 species of diurnal raptors (see appendix 1). Out of the 32 species, three species belong to IUCN's critically endangered category (White-backed vulture *Gyps bengalensis*, Red-headed vulture *Sarcogyps calvus* and Slender-billed vulture *Gyps tenuirostris*), one endangered (Egyptian vulture *Neophron percnopterus*), three vulnerable (Pallas's fish eagle *Haliaeetus leucoryphus*, Indian Spotted eagle *Aquila hastata* and Greater- spotted eagle *Aquila clanga*), and two near threatened (Lesser-fish eagle *Ichthyophaga humilis* and Cinereous vulture *Aegypius monachus*). However, this protected area is facing serious threat due to increasing human population outside as well as inside the park. Habitat degradation in Rajaji is largely due to small-scale biomass extraction by (i) *gujjars* within the park boundary and (ii) villagers living on the fringes of the national park (Figure 1). Gujjars, a semi-nomadic pastoral community, rely heavily on forests for fodder to feed their buffaloes that support their dairy product based economy, as well as for fuel wood and timber (Johnsingh et al., 2004). Villagers, on the contrary, utilize forest largely to collect firewood, timber and cattle grazing for sustenance and livelihood (Kaushik et al., 2012). Almost a decade back, a major relocation program was undertaken to free a part of Rajaji from resource extraction pressure due to *gujjars* (Kurien et al., 2007). This resulted in the establishment of a disturbance gradient across the study area. Areas in the interior of the forest are hilly, rugged and have no or few *gujjar* settlements and therefore have low level of disturbance.

Whereas areas near the park boundary are flat and have high disturbance due to *gujjars* as well as villagers living at the fringes.

An important reason for selecting this landscape was availability of baseline data on habitat, anthropogenic disturbance gradient and bird community parameters (mainly passerines) from a recently conducted research project by the investigator (2009-2012). Results of the completed study point towards considerable changes in vegetation structure at tree and shrub layer due to biomass extraction by local communities. Lopping of trees for fodder collection led to canopy thinning and invasion of an exotic weed, *Lantana camara* in the landscape (Kaushik et al. 2013). Overgrazing by livestock has severely impacted the structure and composition of native shrub species. All these changes in the habitat elevated overall bird species (mainly passerines) richness and density during both breeding and non-breeding season. To understand the effect of such modification in the prey availability and habitat structure on raptors, I proposed this study in the landscape with the following objectives.

- 1) To examine the effect of habitat features and disturbance on raptor richness
- 2) To examine the effects of anthropogenic disturbance and habitat on the distribution and habitat use patterns of raptor species

Plate 1. Different small extractive disturbances in study area A: Lopping, B: Grazing, C: Fire wood collection, D: Bhabar grass collection



2. MATERIAL AND METHODS

2.1 Study Area

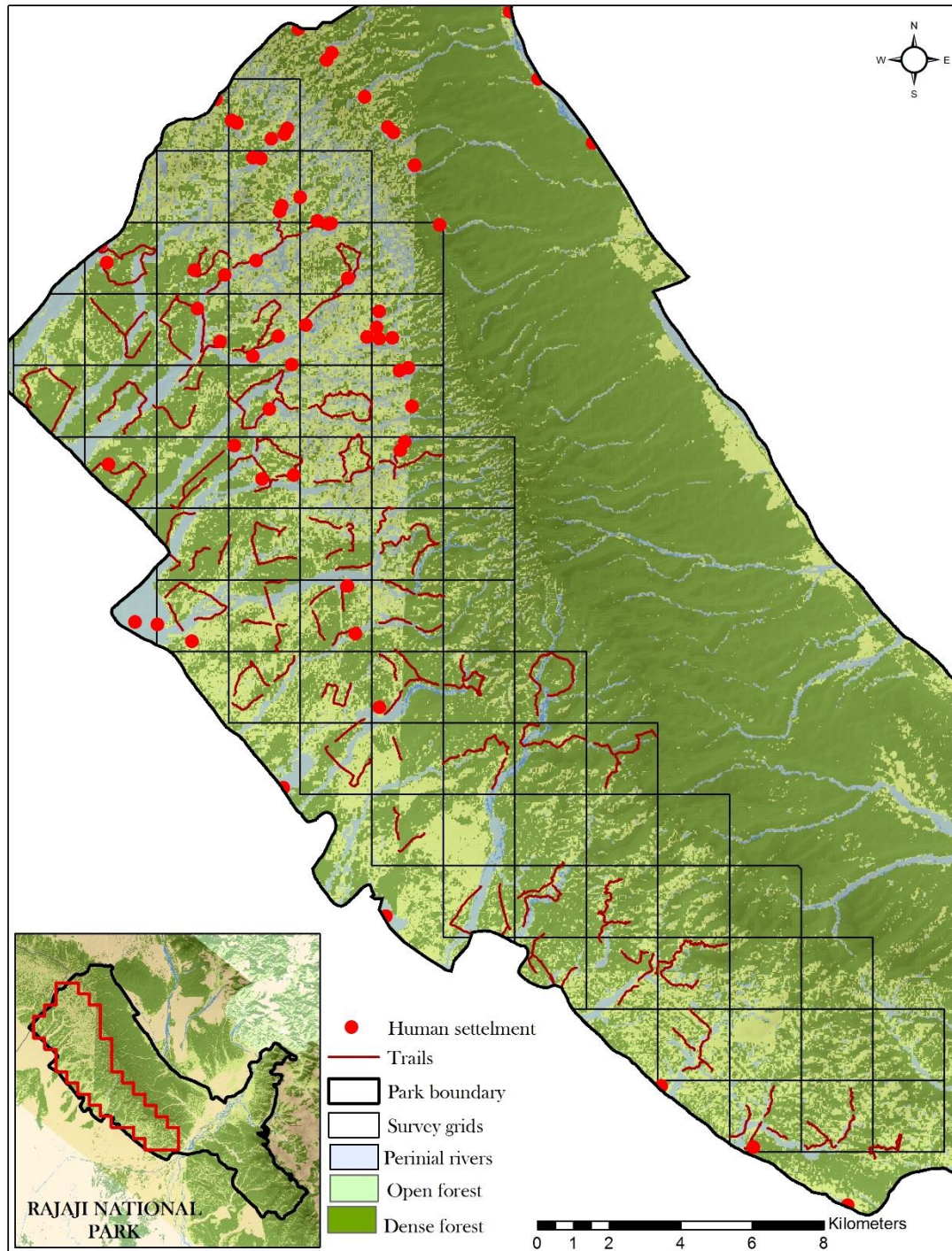
I carried out this study in the southern aspect of the Shiwalik ridge in the dry and hill forests of Rajaji (between Mohand and Ranipur forest gate) covering an area of approximately 250 Km² (Figure 1). The study area lies in the subtropical zone and has a moderate monsoon climate. Mean minimum temperature during winter ranges between 3-5 °C and in summer temperature reaches to 44°C. Mean annual precipitation in the study area ranges between 1,600-1,800 mm. Most of the precipitation occurs during July-September from the southwest monsoon. Altitude varies from 300 to 1000m above mean sea level. This region has a prominent north-west south-east ridge running through the middle of it. Southern side of the ridge recognized for its rutted topography with a number of steep ridges emanating from main Shiwalik ridge with narrow valleys between them. These valleys accommodate seasonally swift rivers locally known as “Rau” (dried river bed). Two forest types with maximum representation in the study area are 1) *Shorea robusta* dominated forest running all along the base of the ridge and 2) mixed forest largely dominated by *Anogeissus latifolia* trees in the slopes. These two dominant forest types differs in terms of vegetation structure and composition. *Shorea robusta* dominated forest had higher canopy cover, stand basal area and tree height than the mixed forest.

Compositionally, *S. robusta* forest have *Terminalia tomentosa*, *Terminalia bellerica*, *Lagerstomea parviflora* in the middle canopy. Understory is being constituted by *Mallotus phillipensis*, *Ehretia laevis*, *Cassia fistula*, *Miliusa velutina* and *Holarrhena antidysenterica*. *Clerodendrum viscosum*, *Murraya koenigii*, *Colebrookea oppositifolia*, *Adathoda vasica* forms the shrub layer. Common associates of *Anogeissus latifolia* in mixed forest are *Acacia catechu*, *Buchanania lanzan*, *Terminalia tomentosa*, *Bauhinia variegata* and *Ougeinia oojeinensis*. Tree species in the mid-story of this forest type belongs largely to *Ziziphus xylopyra* followed by *Mallotus phillipensis*, *Cassia fistula*, *Ehretia laevis* and *Holarrhena antidysenterica*.

Plate 2. Different habitat type in study area A: Dry river bed (Rau), B: Dry Sal Forest, C: Mixed-Hill Forest, D: Nallah.



Figure 1. Location of intensive study area within Rajaji National Park showing survey trails and human settlement within the park boundary.



Shrub layer is very sparse in this forest type and it is characterized by *Woodfordia fruticosa*, *Nyctanthes arbor-tritis*, *Carissa opaca*, *Limonia acidissima*, *Helicteres isora*, *Flacourtia indica* etc. This forest type in the ridge slopes is also known for its luxuriant grass cover. In between contiguous *S.robusta* forest in plains there exist few patches of old plantations of *Tectona grandis*, *Ailanthus excels*

and *Acacia catechu* etc. Heterogeneity of habitats in form of dry rivers beds, Sal dominated forest, Sal-mixed forest and *Anogeissus latifolia* dominated hilly terrains, rugged-cliffs and plantations etc. have resulted in a raptor rich community.

2.2 Sampling design and survey

I surveyed the study area for diurnal raptors from December 2012 to May 2013 during the breeding season of the raptors to meet the assumption of population closure. Wintering diurnal migrant raptors were also recorded during the surveys. Entire study area was divided into 70 grids of 400 ha (2km x 2km) area. Grid size was selected in such a way that it encompassed the home range of the largest raptor species during breeding season and also could be easily surveyed in a day. Survey trails within a grid were selected using a detailed land cover map, one day prior visiting the site. Using prior experience about the existing routes and trails I selected transects to cover different habitats within a grid (Figure 1). All sample grids were surveyed on foot using pre-existing trails (cattle trails, dry river beds, forest road etc.). In each grid at least four trails (Total length per grid = $4.01_{\text{Mean}} \pm 1.01_{\text{SD}}$ Km, one trail per grid $1.04_{\text{Mean}} \pm 0.24_{\text{SD}}$ Km) were walked and all raptors seen or heard within the boundaries of the grid were recorded. Trails within a grid were not particularly independent as they were sequential. However, transects can be considered independent because raptor movements are confined within the territory during the breeding season thereby imparting spatial independence. All the counts were carried out from 2 h after sunrise to 1–2 h before sunset. I tried to use call playbacks for confirming presence of raptors in the sampled grid however due to unavailability of set guidelines and information about its potential consequences on breeding raptors, its use was discontinued.

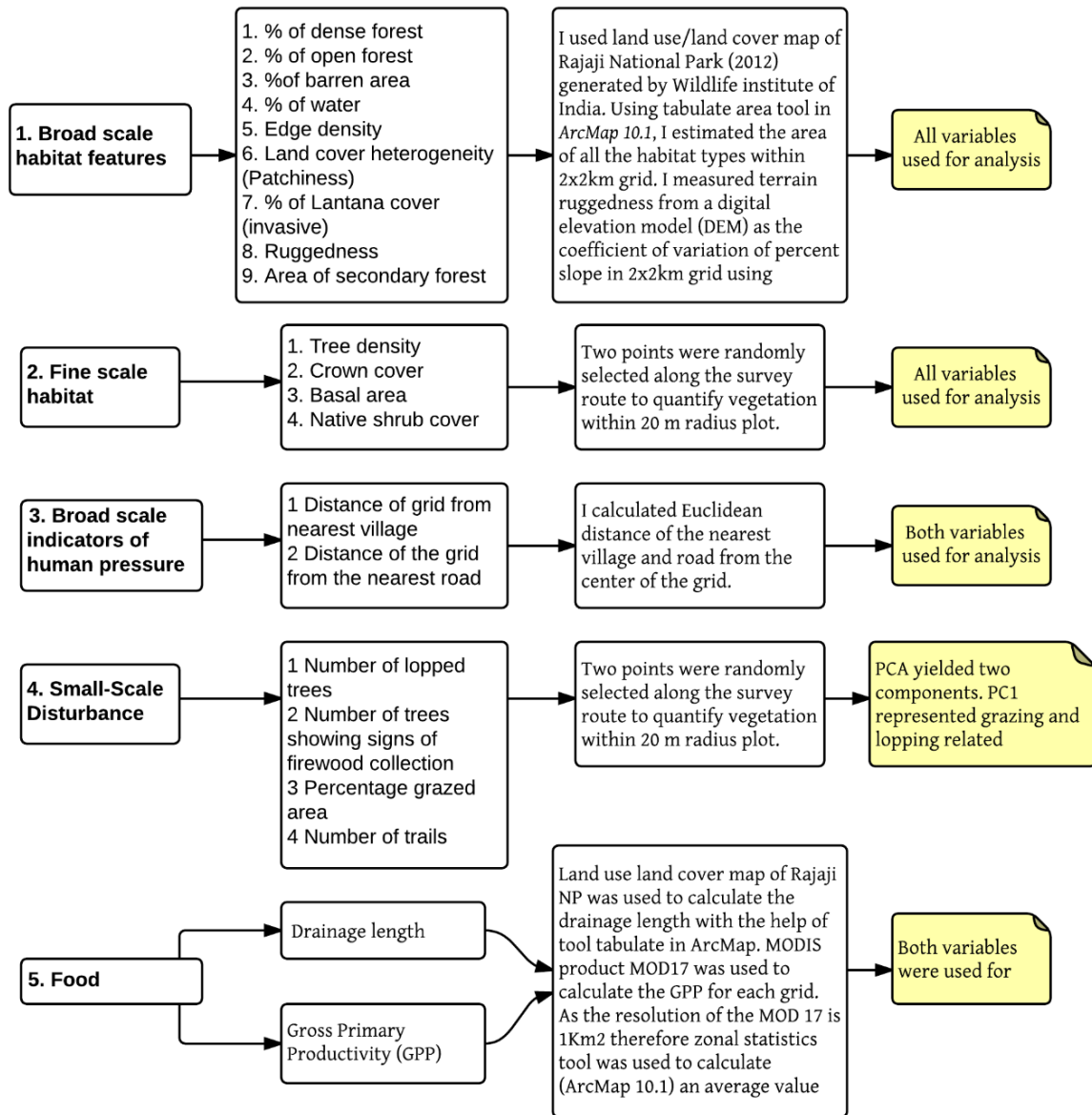
Due to the short duration of the study (December-May 2013) and unexpected inclement weather (frequent sand-storms during the day in the end of March and mid-April), an adequate sample size for reliable precision and accuracy of occupancy estimates was generated using program GENPRES (PRESENCE). For this simulation survey data from 22 grids was used to specify a range of plausible occupancy and detection values (see appendix 2). The simulation results indicated that the estimates of occupancy were relatively unbiased for species with high detection probability (attaining a maximum value of 6% for $\Psi=0.64$, $p = 0.52$; $n=30$) and precision increased with the increase in the number of

sampling sites and survey transects (appendix 2). However the bias of the estimated occupancy was really high for the Shanheen falcon with low detection probability ($p=0.24$). Increase in survey transects (four to five) considerably reduced the bias of the estimated occupancy for this rare and elusive raptor. A total of 47 grids (67% of the total 70 grids) were surveyed throughout the study period. Overall simulation results indicated that bias in occupancy for the final models would likely be trivial (% bias < |6%|) if the number of survey grids exceeded 40 for the common raptor. However for raptors with low detection probability increase in both number of survey grids and survey transects was necessary to reduce the bias in estimated occupancy, thereby indicating that estimates derived from a total of 47 cells would be relatively unbiased.

2.3 Habitat and disturbance variables

Data on vegetation and disturbance variables that could potentially influence the raptor species distribution was collected from raptor survey trails. On each survey trail, two points were randomly selected to collect data on vegetation and anthropogenic disturbance, totaling to eight plots per grid. In each 10m radius plot, I recorded the total number of trees and species identity, girth at breast height, canopy spread (in two perpendicular diameter). I measured percent canopy cover as the average of crown-cover readings taken in four cardinal directions from the quadrat-center by a spherical densiometer. I estimated spread of major shrub (native and non-native) within the sampling plot (10m radius) through ocular estimation. A 20m radius plot was used to collect information on extractive disturbances (fire-wood collection, lopping and grazing). In each plot, I counted the number of trees showing the sign of lopping to find the intensity of lopping, percentage area grazed by livestock was estimated visually and number of trees showing signs of cutting was counted for estimating fire-wood collection. Apart from these variables, I collected information about eco-geographical features using the remotely recent land-cover map of Rajaji and remotely sensed data (see Figure 2).

Figure 2.Method of collecting and extracting variables used for modeling raptor species richness.



3. DATA ANALYSIS

I analyzed the effect of habitat and anthropogenic disturbance on raptors both at community and species level. Landscape variables expected to influence raptor species and community characteristics were extracted for each grid using program *ArcMap 10.1* (See Figure 2). Human proximity was quantified from village and road layers in program *ArcMap 10.1* (ESRI, 2008). At each plot, two variables were measured, Euclidean distance of villages and road from the center of the grid. All the grids were segregated into two groups, exterior and interior, based on their proximity to the human settlements. Grids within two kilometers to the human settlement were categorized as exterior and otherwise interior. This cut off range was decided on the basis of the previous studies in this landscape investigating relationship of disturbance with human settlements (Kaushik et.al., 2013, Kurien et al. 2007). Prior studies indicate a significant relationship between disturbance and human settlement where disturbance decreased with increasing distance from the settlement and declined considerably after 2km from the village. Gross Primary Productivity (GPP), a proxy for available energy was calculated for each grid using MOD17, a MODIS product. This product provides GPP information for terrestrial and aquatic ecosystem at a resolution of 1km². As the GPP for a grid varied over the years therefore an average value of past ten years was used for analysis.

3.1 Community response to habitat features and human disturbance

I pooled observations from all transects within a grid to calculate encounter rate, species richness and diversity. Species wise encounter rates were number of sightings per km (counts/trail). Richness was estimated through Jackknife-1 estimator and diversity by Shannon-Weiner index using software PC-ORD (McCune and Mefford, 2006). I used Welch-two sample t-test to investigate the differences in raptor community parameters between grids located in the interior and exterior of the park (far and close to the human habitation). Differences in encounter rate between interior and exterior grid for each species was tested using non-parametric Wilcoxon signed-rank test. I used generalized linear model to examine the effect of habitat and disturbance on raptor richness. I built a set of different models based on *a priori* hypothesis and compared them using information theoretic approach. I chose Akaike information criterion for small sample sizes (AICc) for model selection since the ratio of sample

size (n) and number of parameters (K) was small (<40, see (Burnham and Anderson 2002). All explanatory variables were z-standardized (with zero mean and unit standard deviation) to make the variables mutually comparable. Most of the predictor variables expected to be auto-correlated and inclusion of highly collinear explanatory variables in the model results in (1) inaccurate model parameterization (2), decreased statistical power and (3) exclusion of significant predictor during model creation (Graham 2003). Therefore, I checked for correlation between all the explanatory variables before including them in the model and only variables with negligible correlation were used in the model building. All the predictor for the best model were checked for multicollinearity by VIF test. I validated the final model through residual diagnosis using *plot* function in program R Version 3.0.2 (Appendix 4).

3.2 Habitat use and distribution of raptor species

I conducted occupancy modeling to examine habitat use for raptor species using single–species single-season models in program PRESENCE 6.2 (Hines, 2006). However, occupancy modeling could not be carried out for all raptor species owing to either lack of variation in detection history or too few detections (see Table 1). Occupancy analysis use simultaneous logistic regression to model detection probability (p) on the site and survey covariate and probability of occurrence on the site covariates. Site covariates, which cannot change during the study period, indicates the habitat preference of a species. Whereas survey covariates, that could vary among surveys, models differences in detection of a particular species (habitat type, time of the day, observer etc.). All the covariates expected to influence the occupancy (ψ) and detectability (p) were checked for correlation and variables with negligible correlation were used for model building. Vegetation structural features, eco-geographical features, anthropogenic disturbance and indicators of food resources (GPP, drainage length) were selected as the site covariates. All the site covariates were continuous and were standardized using z-transformations to bring them at the same scale. Transect type was the selected survey covariate in this study as it was expected to influence the raptor detection therefore all the survey transects were segregated into three group according to the degree of openness. Transects along the dry river beds and hilly terrains provide detection over a large area therefore grouped together in “highly-open category” whereas forest and

nallah belonged to category “low-open category”. Forest road and degraded plantations had moderate visibility therefore grouped in “moderate-open category”.

A set of *a priori* hypotheses were constructed (Appendix 3) for modeling the occupancy (ψ) and detection (p) for each species and best model was selected based on Akaike information criteria (appendix 5; Burnham and Anderson 2002). Chi-square goodness of fit test was used for inspecting the fit of the model to data (MacKenzie and Bailey, 2004). In case where more than one model explained the variation in occupancy for a species, estimates for ψ and p were obtained through model averaging (Burnham and Anderson, 2002). Summed AIC weights of models in which a covariate occurred was used to determine the overall model support for each covariate in explaining probability of habitat occupancy/ use.

4. RESULTS

A total of 47 grids covering 188 km² was surveyed along 184.04 km trails. During the entire survey, a total of 826 individuals of 21 raptor species were observed. The number of raptor species observed within a grid ranged from 1 to 11. Raptors with highest encounter rate was Himalayan griffon *Gyps himalayensis*, Egyptian vulture *Neophron percnopterus* and Crested-serpent eagle *Spilornis cheela* (Table 1). Critically endangered, White-rumped vulture *Gyps bengalensis* was seen only on two occasions during the survey period near *bam rau*. Black eagle *Ictinaetus malayensis* and Shaheen falcon *Falco peregrinus peregrinator* were observed very rarely.

4.1 Community response to habitat features and human disturbance

Raptor richness as well as diversity was higher in the grids located far from the villages in the interiors of the Rajaji (Figure 3a & 3b) however the result was close to significant for the diversity ($t=1.951$, $p=0.059$) and not significant for richness ($t=1.30$, $p=0.20$). Raptor richness was best explained by combination of drainage length, percentage of water, area of secondary forest and distance from the village (Table 2). Raptor richness had strong positive relationship with area of secondary forest and drainage length within the grid (Table 3). A negative relationship between raptor richness and distance from the village was observed however the value of the estimate was not significant. Predictor variables for the best model had VIF value less than 5, indicating lack of multi-collinearity.

Overall raptor encounter rate did not differ significantly between grids located close and far from human settlement ($W=289.5$, $p=0.58$). However, encounter rate differed between two treatments for certain species.

Table 1. Raptor species observed during the entire survey period.

Species	Scientific name	Individuals (observations)	Encounter rate	Naïve occupancy
RESIDENT				
Red-headed Vulture	<i>Sarcogyps calvus</i>	21(15)	0.12	0.33
White-backed Vulture	<i>Gyps bengalensis</i>	2(2)	0.01	NA
Crested-serpent Eagle	<i>Spilornis cheela</i>	103(38)	0.52	0.80
Changeable-hawk Eagle	<i>Nisaetus cirrhatus</i>	53(32)	0.38	0.67
Bonelli's eagle	<i>Aquila fasciata</i>	14(9)	0.08	0.20
Black Eagle	<i>Ictinaetus malayensis</i>	2(2)	0.01	0.04
Short-toed Snake Eagle	<i>Circaetus gallicus</i>	7(6)	0.03	0.13
Oriental-honey Buzzard	<i>Pernis ptilorhynchus</i>	14(9)	0.07	0.20
White-eyed Buzzard	<i>Butastur teesa</i>	82(29)	0.38	0.63
Common Buzzard	<i>Buteo buteo</i>	1(1)	0.01	NA
Shaheen Falcon	<i>Falco peregrinus peregrinator</i>	8(5)	0.02	0.11
Black-shouldered kite	<i>Elanus axillaris</i>	9(6)	0.04	0.13
Black Kite	<i>Milvus migrans</i>	13(5)	0.07	0.11
Shikra	<i>Accipiter badius</i>	65(27)	0.34	0.57
MIGRANT				
Egyptian Vulture	<i>Neophron percnopterus</i>	82(25)	0.43	0.52
Eurasian Griffon	<i>Gyps fulvus</i>	102(25)	0.53	NA
Himalayan Griffon	<i>Gyps himalayensis</i>	200(47)	1.16	1.00
Cinereous Vulture	<i>Aegyptius monachus</i>	19(12)	0.1	0.26
Steppe-Eagle	<i>Aquila nipalensis</i>	7(4)	0.06	0.09
Tawny Eagle	<i>Aquila rapax</i>	3	0.01	0.04
Common Kestrel	<i>Falco tinnunculus</i>	19(12)	0.06	0.26

Note: Individual indicates total number of sighting of a species, encounter rate refers to the number of individual per km and naïve occupancy is the number of sites species was present to the total number of surveyed grids.

Figure 3(a) and (b). Boxplot of Raptor species richness and diversity between grids located at close and far from the village.

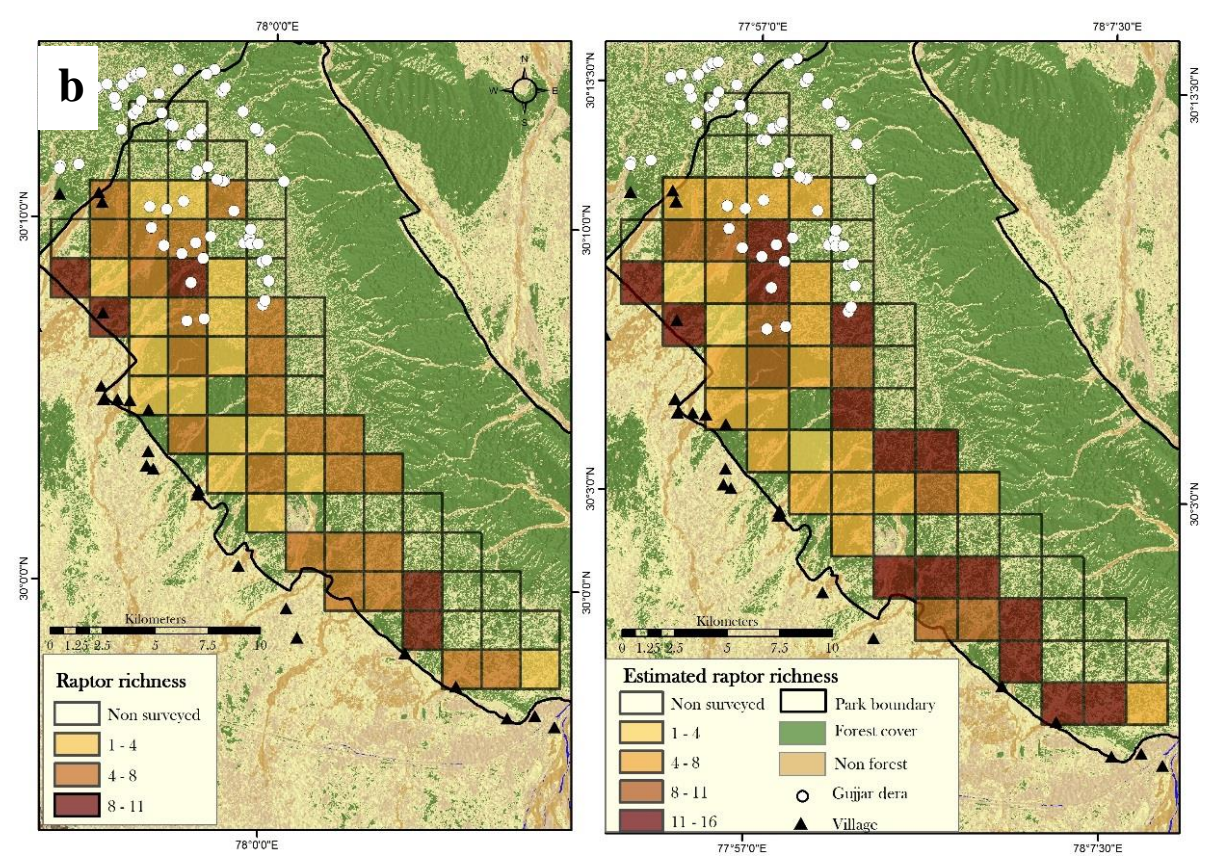
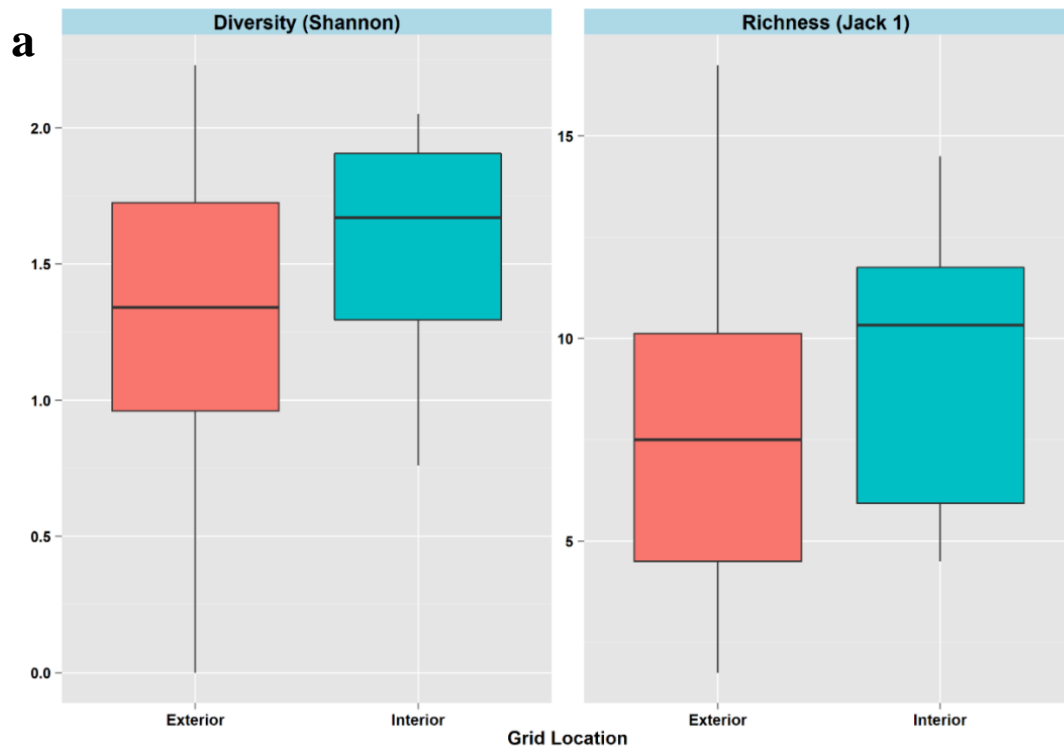


Table 2. Raptor richness was modeled with logical combinations of potential predictors using generalized linear mixed model. Best model was selected on the basis of minimum AIC value (in bold).

HYPOTHESIS	DF	AICc	Δ AICc
L_drain+ per_water + Area_secondaryfor + Dist_vill	6	240.03	0.0
Dist_vill+L_drain + per_water	5	242.69	2.66
Null	2	248.87	8.85
Dist_vill+overall_disturbance	4	250.55	10.5

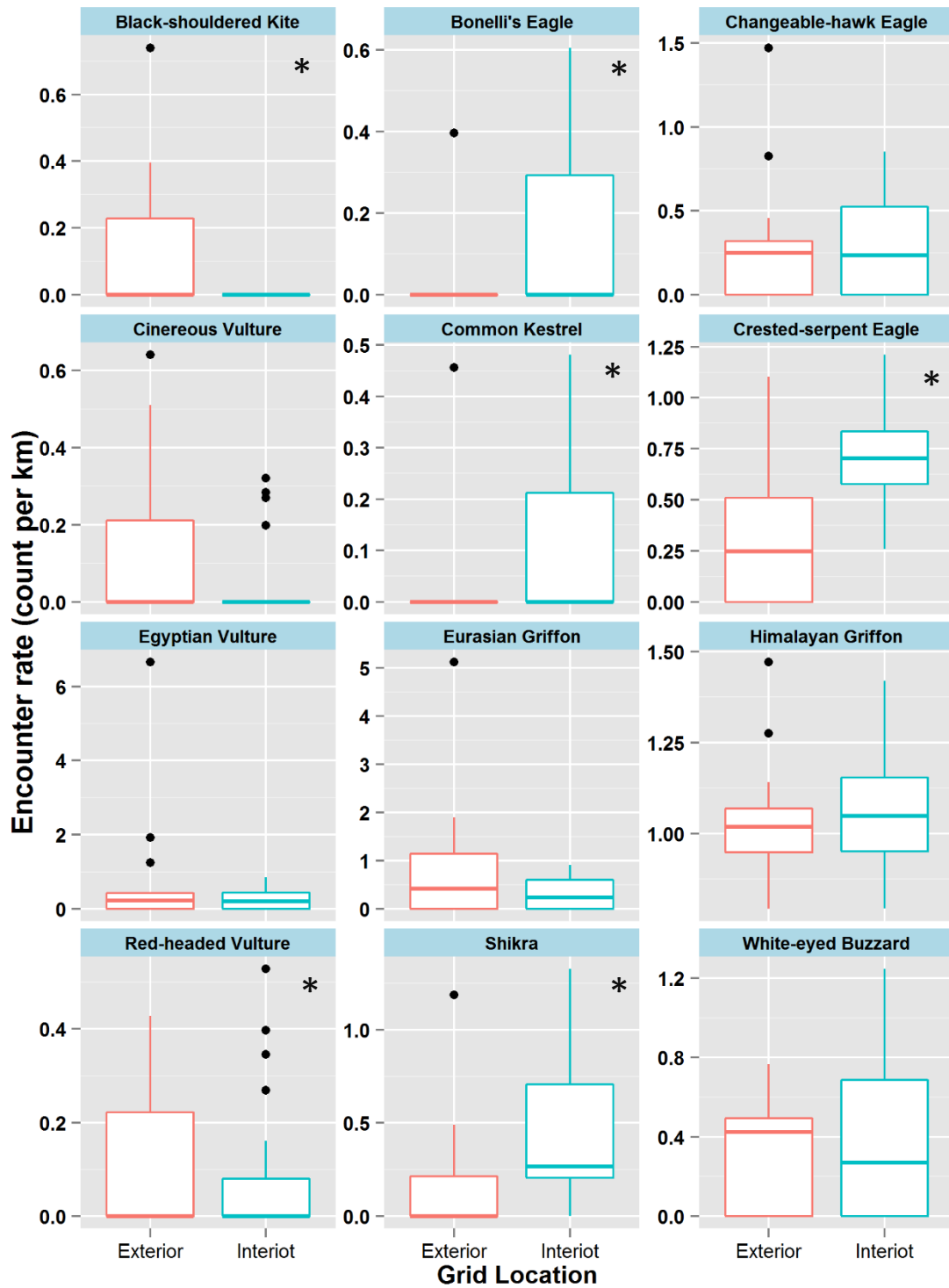
Note: L_drain=drainage length, per_water = Percentage of water, Area_secondaryfor = Area of secondary forest, Dist_vill = Distance from the village

Table 3. Summary of generalized linear model analysis showing coefficient estimates for raptor richness. Since variables had been scaled and centered, predictors are expressed in unit standard deviations.

Variable	B-estimate	SE	Z-value	Probability
Area of Secondary Forest	1.14	0.51	2.24	0.03
Distance from village	-0.61	0.57	-1.08	0.29
Drainage length	1.38	0.52	2.66	0.01
Percentage of water	0.77	0.46	1.67	0.10

Encounter rate differed significantly between exterior and interior grids for Crested-serpent eagle (W=46, p=0.002), Bonelli's eagle (W=104, p=0.02), Red-headed vulture (W=163, p=0.05), Shikra (W=66, p=0.001), Common Kestrel (W=106, p=0.02) and Black-shouldered kite (W=209, p=0.01). However, for Changeable-hawk eagle (W=157, p=0.89), White-eyed buzzrd (W=144, p=0.58), Himalayan (W=130, p=0.33) & Eurasian griffon (W=140, p=0.55), Egyptian vulture (w=171.5, p=0.75) and Cinereous vulture (w=190.5, p=0.25) it did not vary between interior and exterior grids (Figure 4).

Figure 4. Species-specific encounter rate among grids located closer (exterior) and distant (interior) to human settlements (* statistically significant difference in encounter rate across grids).

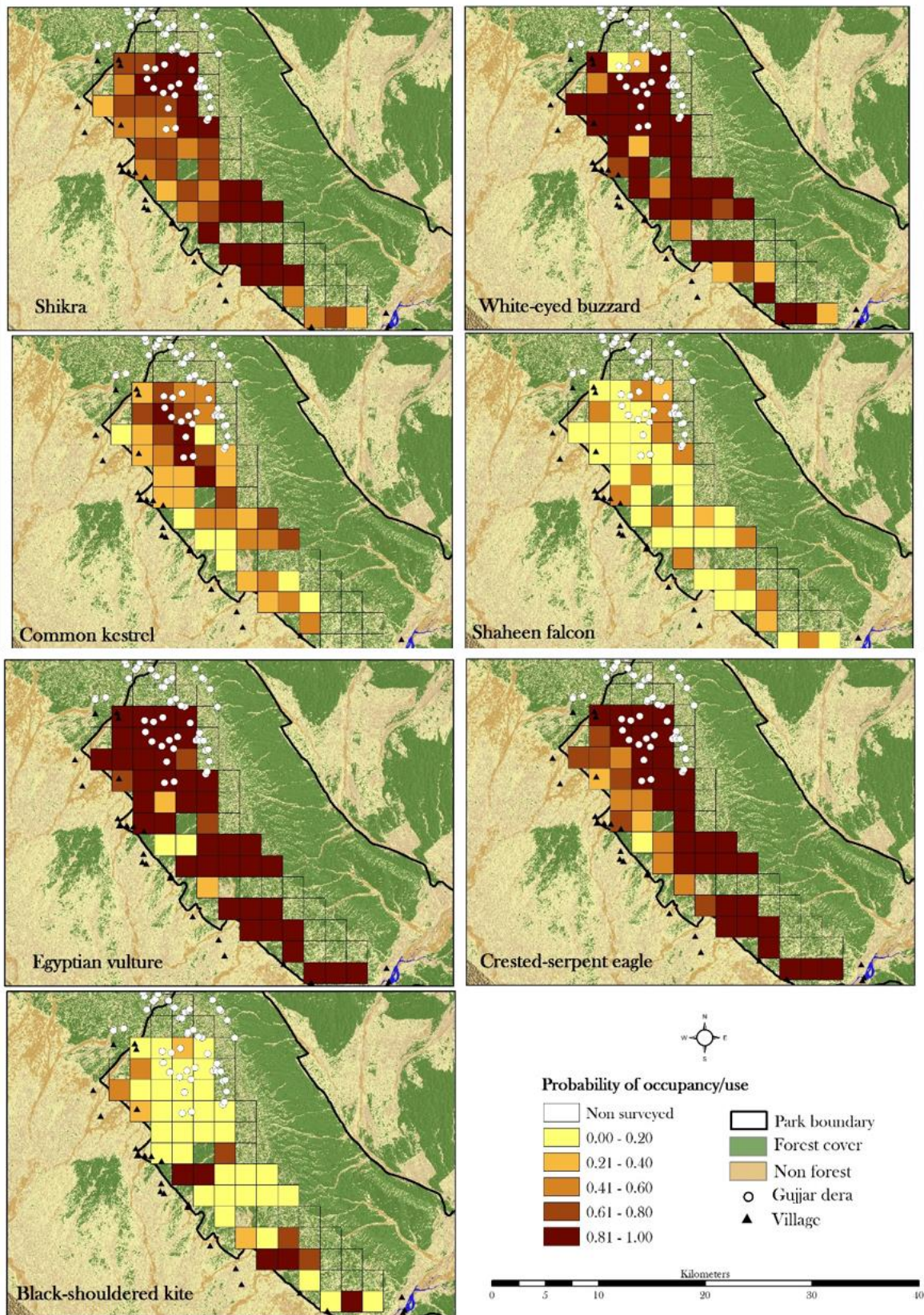


4.2 Occupancy patterns of raptor species

Out of the 21 species, covariate modeling could be performed only on 7 species (figure 5). Rest of the species did not have enough detection histories which resulted in unreliable estimates of p and ψ . For the species with enough detection histories, models with covariates on p and ψ performed better than the dot model (no covariate model). Bias corrected estimates of proportion of area occupied was similar to their respective naïve estimates for more than 50% modeled species, indicating that signs were adequately detected during sampling. Whereas signs were not perfectly detected in case of Egyptian vulture, Common kestrel and White-eye buzzard as the naïve estimates differed greatly from the modeled estimates.

For most species, modeling for detection probability did not result in improvement of overall model. Only in case of Crested-serpent eagle detection was found to be positively correlated with “less-open” category of survey transects. Crested-serpent eagle and Changeable-hawk eagle were the most common raptor in the study area with the highest naïve occupancy (Table1). Bonelli’s eagle was found mostly associated with the rugged hilly forest, sighted only in the interior grids of the study area. Black eagle had the lowest naïve occupancy amongst eagle and was sighted rarely only in the interior of the forest. Steppe eagle and Tawny eagle are both migrant raptors and were also detected during the survey mostly in the grids which were located on the periphery of the study area. Himalayan and Eurasian griffons were the commonest migratory vulture sighted mostly in large flocks in all the grids across the study area. Egyptian vulture became more common with the approach of summer and was easily sighted around the dry river beds foraging with other vulture species as well as in pairs. It was found in 52% of the surveyed grids. Red-headed vulture was sighted in 33% of the surveyed grids and largely sighted singly soaring above the dry river beds (Table1).

Figure 5. Occupancy probability of seven raptor species across the sampled grids of 4Km².



5. DISCUSSION

This is a first systematic study to survey and ascertain the factors responsible for raptors habitat use in the study area. Present study indicate towards the endangered future of some imperiled species in the study area such as White-backed vulture (critically endangered) which was seen only on two occasions during the study period. Another critically endangered raptor, slender-billed vulture although reported from the study area (Pandey et al., 1994) was never seen during entire survey period. The results of this study should serve as a baseline for future research on some of the rare and data deficient raptors of India such as Shaheen falcon. Three nesting locations were found during the study which could be used for studying the behavioural ecology of this rare raptor. Moreover, the roosting site information of Egyptian vulture recorded during the study was the largest congregation reported in the recent years from the entire Uttarakhand state (Rahmani and Mohan, 2014). This indicates the conservation value of the study area for this species as well as for other raptors.

5.1 Effect of anthropogenic disturbance on raptors

Proximity to human habitations have been found to be strongly associated with loss and degradation of habitat, hunting and biomass extraction in tropical forest of various countries (Karanth et al., 2006; Muchaal and Ngandjui, 1999; Thapa and Chapman, 2010). Therefore proximity to human habitation has been used as an important indicator of human disturbance in a number of studies. In this study area, human disturbance in form of lopping of trees for fodder was higher near the *gujjar deras* and decreased after 2km (Kurien et al. 2007).

Raptor community as well as species responded differently to habitat degradation in different studies. Raptor species richness and abundance in Baja California, Mexico, increased by moderate human disturbance (Rodríguez-Estrella et al., 1998) whereas it decreased with human disturbance in Africa and Argentina (Anadón et al., 2010; Carrete et al., 2009). This difference, in general can be explained by the dissimilarities in niche breadths of raptor species constituting the community. Raptor assemblages in temperate regions contain more generalist species whereas tropical raptors are more specialists and therefore are more threatened to human-induced habitat alterations (Thiollay 1996). In the current study, species richness was higher in the grids located in the interior of the park compared

to ones closer to human habitation which indicate towards the presence of more specialized species in the community (see Figure 3). Species diversity and overall encounter rate did not differ among grids located at close and far-off distances from the human habitation. However, species specific analysis revealed differences in encounter rate among grids located far and close to human habitation (see Figure 4). Mainly, large forest dependent species (Red-headed vulture, Bonelli's eagle and Crested serpent eagle) had higher encounter rate in grids located in the interior parts of the park whereas, migrant and some generalist resident raptor species (Himalayan griffon and White-eyed buzzard etc.) were uniformly distributed throughout the study area. These results are in consensus with studies conducted in arid African forest where migrant species richness increased with increasing human habitation whereas resident species declined (Anadón et al. 2010). In West Africa, two migrants raptors did not show any response to disturbance due to human habitation whereas all resident raptors exhibited a negative trend (Thiollay 2006). Although overall richness was higher in the interior grids, the results of modeling showed a positive linear relationship of species richness with secondary forests. This could be explained by the increased influx of the generalist open forest species such as Black-shouldered kite, White-eyed buzzard. Similar results were seen in tropical rain forest of southern India where habitat degradation benefitted open forest species by expanding available habitat (Thiollay 1993). Moreover, some species such as Shikra and Changeable hawk eagle prefer moderate degradation and thereby resulted in highest richness at moderate disturbance.

5.2 Species specific habitat occupancy

Out of the 14 resident raptors recorded during the study, Crested-serpent eagle had the highest proportion of area occupied (80%) followed by Changeable-hawk eagle (67%), White-eyed buzzard (63%) and Shikra (57%). Thiollay (1993) found that percentage of edge had a strong association with occurrence of Crested-serpent eagle, Changeable-hawk eagle and Shikra in tropical rain forests. Though, known to forage in different type of habitats, all these species breed in the forest (Thiollay 1993). Interestingly, all these species seem to benefit by moderate level of disturbance but occupancy modeling showed that Crested-serpent eagle and Shikra had low-occupancy probability in the grids located closer to human habitation (see Figure 5). This pattern in occupancy was attributed to

ruggedness which was higher in the interior grids and positively influenced occupancy for these two species.

Shaheen falcon, Common kestrel and Bonelli's eagle were observed foraging in the interior parts of the park especially in the ridges. Shaheen falcon is a resident raptor known to breed in the rocky outcrop than forested areas (Naoroji and Schmitt 2007). Presence of dry perennial river beds and ruggedness dictated the habitat use by Shaheen falcon in the study area. Less sightings of Shaheen falcon during the study period could be attributed to either low abundance or low survey effort in the potential habitat of the species. Habitat use of Common kestrel was positively influenced by the land-cover patchiness and openness. This species was mostly observed foraging along the hilly ridges and perennial river beds. Habitat characteristic rather than human disturbance appeared to govern the habitat use by the species.

Cuthbert et.al.,(2006) estimated a 90% decline for Red-headed vulture populations in India since 1990s. The species experienced severe decline mainly due to increased exposure to diclofenac (Cuthbert et al., 2006) after disappearance of *Gyps* vulture. Red headed vulture encounter rate was found to be higher in the interior grids.

With a decline rate of 35% in India and >50% in Europe (Cuthbert et al. 2006), Egyptian vulture is categorized as endangered species that migrates to the study area in late winters and stays till mid-summer (January- May).However, the highest congregation of Egyptian vulture within the study area was observed near Ranipur grid (close to Haridwar town) within the park boundary. Widespread occurrence of the species in the study area could be explained by its broad niche breadth (Naoroji and Schmitt, 2007). It feeds on a variety of food resources and also scavenges near human habitation. Within the study area, species was often seen soaring near a *gujjar dera* within the grid. Drainage length and percentage of perennial river, "rau" governed the occupancy probability of this species. Areas around the drainages in Rajaji are very dry and are associated with increased detection of carrions. Broad niche breadth in terms of food and foraging habitat explains the equal encounter rate of the species among grids located near and far-off from human habitation.

Cinereous vulture, Himalayan & Eurasian griffon were other migrants present in the study area which found in all the grids.

White-eyed buzzard on the other hand, is a species of scrub forest and was seen in almost all the forest types and especially in the highly degraded areas (Shahabuddin et al. 2006). Percentage of barren land had the positive effect on the habitat use by White-eyed buzzard in the study area. Black-shouldered kite, is a species associated with grasslands and streams. In Europe, gradual increase in cultivation has resulted in range expansion of the species (Balbontín et al., 2008). In the study area, the species showed higher probability of occupancy in grids closer to the boundary of the national park which abuts the cultivated areas of the villages (see figure 5).

6. CONCLUDING REMARKS

The occupancy patterns of raptors were indicative of less use of the areas closer to human habitation. The study points to the following two key aspects demanding immediate attention: a) habitat degradation within the forest and habitat loss on the fringes and b) changes in “life-style” of *gujjars* inside the park. The former is mainly a result of the rapid increase in developmental activities including establishment of new industries in the fringes of the park, conversion of agricultural lands to urban areas and the increase in the human and livestock population both inside and in the villages adjoining the park. Whereas, the latter is a result of the recent changes in *gujjar* movements from a semi-nomadic to a more sedentary nature.

The increased anthropogenic pressure is especially evident in the southern aspect of Rajaji National Park (WII 2005). Rapid changes along park boundaries could affect the migrant (e.g., Egyptian vulture, Steppe eagle, Tawny Eagle) and generalist resident raptors (e.g., White-eyed buzzard, Shikra) which forage in barren and/or agricultural areas.

Due to the cessation of *gujjar* migration, the forest is now experiencing intense year-round grazing pressure. As the preferred fodder plants (*Anogeissus latifolia*, *Terminalia tomentosa*, *T. bellirica* etc.) are being over-utilized by *gujjars*, their availability has drastically reduced in the study area. Consequently, less palatable plants species such as *Shorea robusta* (Sal) and *Mallotus Phillipensis* (Rohini) are increasingly harvested. This is leading to the thinning of canopy and thus reducing nest sites for many raptors. An instance of nest abandoning by Crested-Serpent Eagle, due to lopping of a nesting tree was recorded during the study. Furthermore, the timing of collection of Bhabar grass

(*Eulaliopsis binata*) by villagers and *gujjars*, coincides with the breeding season of cliff-nesting birds such as Shaheen Falcon, Bonelli's Eagle, Mountain Hawk Eagle and Black Eagle. The increasing human pressure and biomass extraction practices could negatively influence the long term persistence of raptors in the study area (also see Richardson and Miller 1997).

Given the paucity of data on diurnal raptors, this study should serve as a baseline for future research on some of the rare and less-studied raptors of India. However, to conclusively arrive at the precise nature of the problem and for robust conservation planning, long – term studies are required. Future conservation priorities in Rajaji should hence focus on long-term research to address the following questions a) to study habitat use by raptors both during breeding and non-breeding season, b) to study the effect of land-use change in the fringes of the park on the migratory raptors and, c) to study possible effects of invasion and spread of *Lantana camara* on the foraging ecology of raptors. Studies on the behavioural ecology of threatened raptor species should also be initiated.

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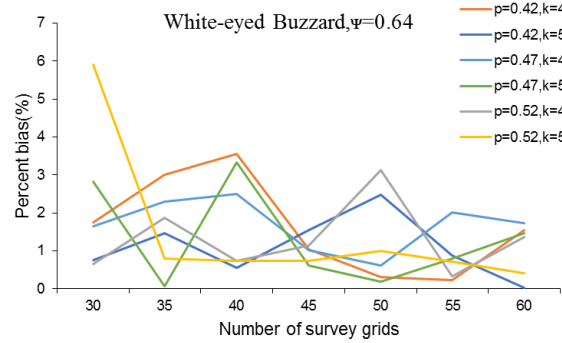
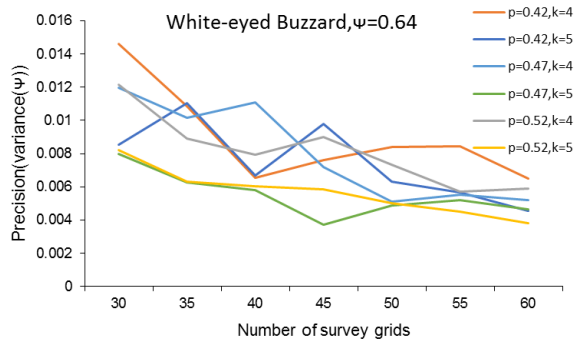
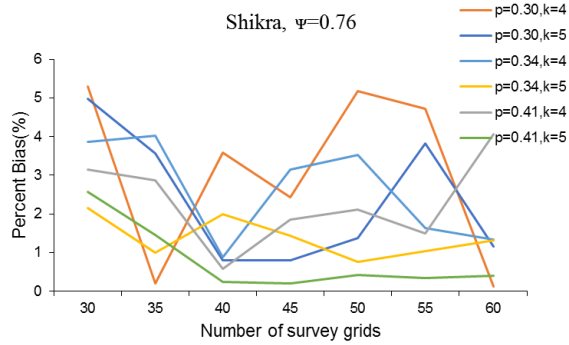
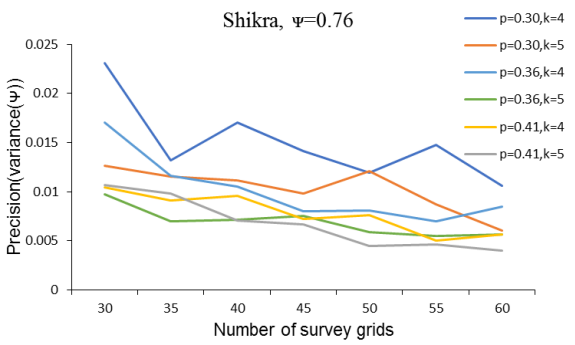
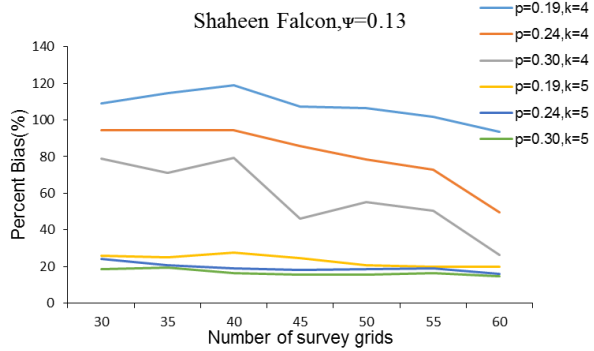
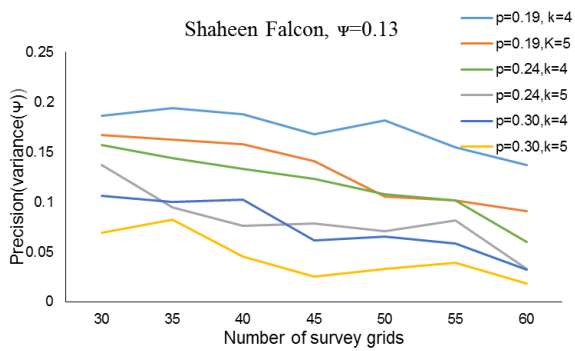
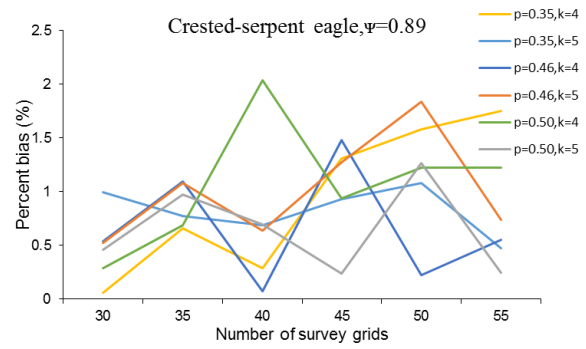
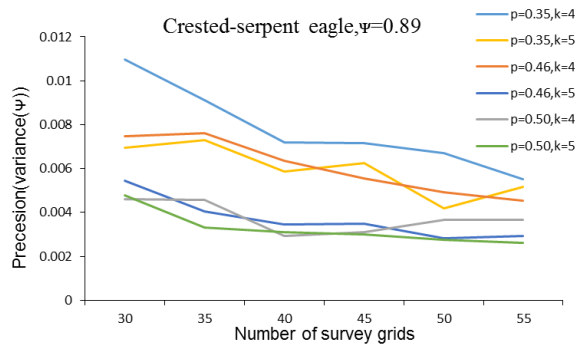
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Appendix 1. Raptor species of Rajaji National Park with their conservation status and known habitat preference (Naoroji and Schmitt, 2007; Pandey et al., 1994).

Common name	Scientific name	Conservation status	Resident Status	Know habitat preference
Besra (Besra Sparrow-hawk)	<i>Accipiter virgatus</i>	LC	R	Forest
Black Kite	<i>Milvus migrans</i>	LC	R	Degraded/Urban areas
Black-shouldered Kite	<i>Elanus caeruleus</i>	LC	R	Agricultural fields/grasslands
Bonelli's Eagle	<i>Aquila fasciata</i>	LC	R	Open country with rugged-Cliffs
Changeable hawk Eagle	<i>Nisaetus cirrhatus</i>	LC	R	Forest Edge
Crested serpent Eagle	<i>Spilornis cheela</i>	LC	R	Forest Edge
Indian Black Eagle	<i>Ictinaetus malayensis</i>	LC	R	Forested Hills
Indian White-Backed Vulture	<i>Gyps bengalensis</i>	CR	R	Open-country
Lesser-fish Eagle	<i>Ichthyophaga humilis</i>	NT	R	Forested river valleys
Mountain Hawk Eagle	<i>Nisaetus nipalensis</i>	LC	R	Forested Hills
Oriental-honey Buzzard	<i>Pernis ptilorhynchus</i>	LC	R	Open-Woodland
Pallas-sea Eagle	<i>Haliaeetus leucoryphus</i>	VU	R	Water bodies
Red-headed Vulture	<i>Sarcogyps calvus</i>	CR	R	Forest
Shaheen	<i>Falco peregrinus peregrinator</i>	LC	R	Hill Forest
Shikra	<i>Accipiter badius</i>	LC	R	Forest edge/degraded forest
Short-toed snake Eagle	<i>Circaetus gallicus</i>	LC	R	Within forest clearings
slender-billed Vulture	<i>Gyps tenuirostris</i>	CR	R	Forest
White-eyed Buzzard	<i>Butastur teesa</i>	LC	R	Open-country
Cinereous Vulture	<i>Aegypius monachus</i>	NT	M	Forest
Common Buzzard	<i>Buteo buteo</i>	LC	M	Open-country
Common Kestrel	<i>Falco tinnunculus</i>	LC	M	Open-Country
Egyptian Vulture	<i>Neophron percnopterus</i>	EN	M	Dry open-country
Eurasian Sparrowhawk	<i>Accipiter nisus</i>	LC	M	Open-country
Eurassian Griffon	<i>Gyps fulvus</i>	LC	M	Forest
Eurassian Sparrowhawk	<i>Accipiter nisus</i>	LC	M	Forest edge
Greater-spotted Eagle	<i>Aquila clanga</i>	VU	M	Wooded areas near water bodies
Himalayan Griffon	<i>Gyps himalayensis</i>	LC	M	Forest
Northern Goshawk	<i>Accipiter gentilis</i>	LC	M	Forest edge
Osprey	<i>Pandion haliaetus</i>	LC	M	Water bodies
Tawny Eagle (Eurasian Tawny Eagle)	<i>Aquila rapax</i>	LC	M	Dry arid country.
Western marsh harrier	<i>Circus aeruginosus</i>	LC	M	Prefers marshes
Lesser-spotted eagle	<i>Aquila pomarina</i>	LC	?	Open-country

Note: Abbreviations used for conservation status (LC-Least concerned, EN-Endangered, VU-vulnerable, CR-Critically endangered, NT-Near threatened) and status (M-Migrant, R-Resident).

Appendix 2. Results of simulations showing percent bias in estimates of probability of occupancy (Ψ), with precision of estimates (variance) for different combination of survey grids and transects.

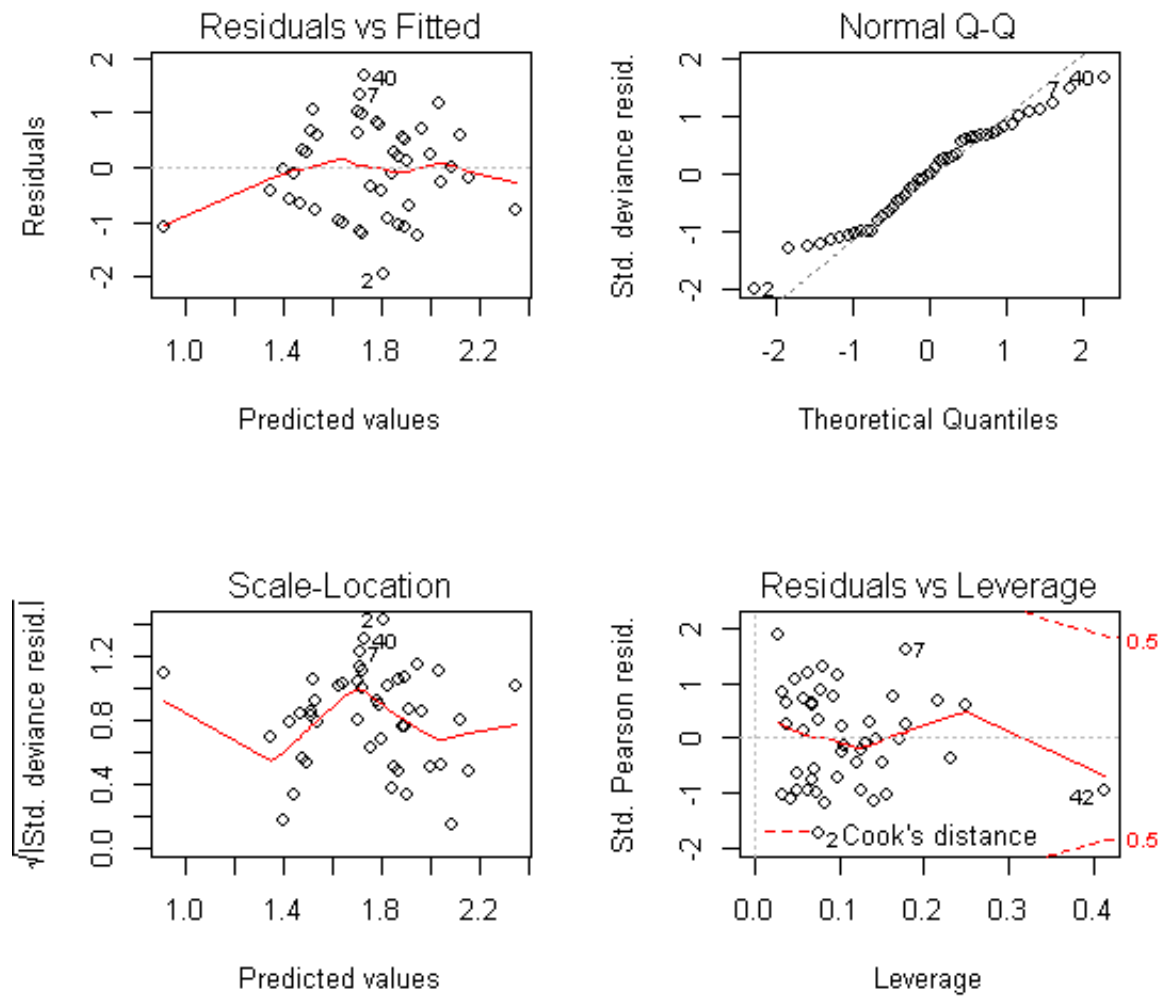


Appendix 3.List of covariates used to model “Probability occupancy” (ψ) and “detection probability) (p) with rationale for selection.

Species	Predictor variable	Rationale	References
Red-headed vulture	<input type="checkbox"/> <i>Percentage of forest cover</i>	Nests on large trees. Non-availability of suitable nesting tree was considered as a reason of decline in its sightings in Saurashtra and Kutch.	Dharmakumarsinhji 1955, Ali 1945 (Thiollay 2006, Thiollay 2007)
	<input type="checkbox"/> <i>Distance from the village</i>	Large scale-human disturbance negatively influenced the species	
Egyptian vulture	<input type="checkbox"/> <i>Percentage of open forest</i>	It's an open forest species therefore expected to be associated with open forest.	(Sarà and Di Vittorio, 2003)
	<input type="checkbox"/> <i>Ruggedness</i>		
	<input type="checkbox"/> <i>Distance from the village</i>	Feeds on a variety of food types and especially seen feeding on the dumping sites therefore it could be positively influenced by the habitation.	
Shikra	<input type="checkbox"/> <i>GPP, Habitat patchiness</i>	High productivity and heterogeneity will lead to high biomass and high diversity of food resources.	(Thiollay 1993)
	<input type="checkbox"/> <i>Ruggedness</i>	Cryptic predator and often sighted in hilly terrain showing admixture of dry river bed and moderately dense forest	
	<input type="checkbox"/> <i>Distance from village</i>	Positively influenced by habitat disturbance.	
Crested-serpent eagle	<input type="checkbox"/> <i>Percent of forest cover</i>	It's a species of dry-deciduous forest type and nests within the forest on large trees.	(Thiollay 1993)
	<input type="checkbox"/> <i>Drainage length</i>	It is being sighted mostly on the trees near the Rau/small streams which acts as a good vantage point for detecting their prey.	
	<input type="checkbox"/> <i>Distance from the village/road</i>	It's a forest dependent raptor and is largely restricted to forest areas during breeding season therefore is expected to decline with increasing disturbance.	
White eyed buzzard	<input type="checkbox"/> <i>Percentage of open forest</i>	It prefers dry scrub forest near agricultural areas	
	<input type="checkbox"/> <i>GPP</i>	Feeds on a variety of food resources from snakes, rodents, frogs, crabs to locusts.	
	<input type="checkbox"/> <i>Distance from village</i>	A species often seen near villages and foraging around agricultural lands	
	<input type="checkbox"/> <i>Overall small disturbance</i>	Small-scale extractive disturbances could positively influence this species by increasing habitat heterogeneity, increasing food resources and decreasing competition by large raptors	
Bonelli's eagle	<input type="checkbox"/> <i>Ruggedness, Percentage of open forest</i>	During survey species was seen mostly around dry river beds in hill forest. Moreover it is a cliff nesting species therefore grids with more hill area are expected to have higher probability of being occupied.	

	<input type="checkbox"/> <i>Small-extractive disturbances (Principal component)</i>	Degradation has been seen to be positively influencing this species in Kumaun Himalayas however high degree of disturbance has been shown to detrimental for species in Spain	(Naoroji and Schmitt, 2007)
Common Kestrel	<input type="checkbox"/> <i>Ruggedness, Percentage of open forest</i>	Prefers open habitat in plains during study period mainly found near hill areas around <i>raus</i> . Nest in cliffs, crevices and disused tree holes.	
	<input type="checkbox"/> <i>GPP, habitat patchiness</i>	Feeds on a variety of food resources therefore patchiness index could influencing its occupancy.	
	<input type="checkbox"/> <i>Small-extractive disturbances (Principal component)</i>	Have been seen foraging near villages and in the vicinity of towns	
	<input type="checkbox"/> <i>Distance from village/road</i>	Has been expected to be benefitted by degradation in Himalayan foothills	(Naoroji and Schmitt, 2007)
Black-shouldered kite	<input type="checkbox"/> <i>Percentage of open forest, drainage length</i>	Often prefers grasslands of riverine floodplains, open woodland, scrubland and even degraded forests.	(Balbontín et al., 2008; Thiollay and Rahman, 2002)
	<input type="checkbox"/> <i>Distance from the village</i>	Feed on insects, lizards, small birds and occasionally on frogs and snakes.	
Changeable-hawk eagle	<input type="checkbox"/> <i>Distance from the village</i>	Mostly sighted foraging near degraded forest near the villages and recorded nesting in highly degraded grids closer to the villages	
	<input type="checkbox"/> <i>Small-extractive disturbances(Principal component)</i>	Small extractive disturbances are expected to benefit the species by increasing prey detectability and increased abundance of generalist prey.	

Appendix 4. Model diagnostic for best model of raptor richness



Appendix 5. Model comparisons to identify ecological and anthropogenic habitat covariates influencing raptor species distribution in the study area from spatially replicated sign surveys during December-April 2013.

Common Kestrel

Model	AIC	ΔAIC	AIC wt	Model Likelihood	K	-2log likelihood
Ψ (<i>landcover</i>), p (<i>highopen</i>)	89.22	0	0.66	1	4	81.22
Ψ (.), p (<i>highopen</i>)	92.63	3.41	0.12	0.18	3	86.63
Ψ (<i>landcover</i>), p (.)	92.8	3.58	0.11	0.17	3	86.8
Ψ (.), p (<i>lowopen</i>)	94.74	5.52	0.04	0.06	3	88.74
Ψ (<i>L_drain</i>), p (.)	96.46	7.24	0.02	0.03	3	90.46
Ψ (.), p (.)	96.87	7.65	0.01	0.02	2	92.87
Ψ (<i>dist_vill</i>), p (.)	98.04	8.82	0.01	0.01	3	92.04
Ψ (<i>disturbance</i>), p (.)	98.32	9.1	0.01	0.01	3	92.32
Ψ (<i>rugged</i>), p (.)	98.83	9.61	0.01	0.01	3	92.83
Ψ (<i>rau</i>), p (.)	98.85	9.63	0.01	0.01	3	92.85

White-eyed buzzard

Model	AIC	ΔAIC	AIC wt	Model Likelihood	K	-2log likelihood
Ψ (<i>barren</i>), p (.)	211.4	0	0.43	1.00	3	205.4
Ψ (.), p (.)	214.06	2.66	0.11	0.26	2	210.06
Ψ (<i>dist_vill</i>), p (.)	215.08	3.68	0.07	0.16	3	209.08
Ψ (<i>L_drain</i>), p (.)	215.12	3.72	0.07	0.16	3	209.12
Ψ (<i>rau</i>), p (.)	215.46	4.06	0.06	0.13	3	209.46
Ψ (<i>rugged</i>), p (.)	215.85	4.45	0.05	0.11	3	209.85
Ψ (.), p (<i>modopen</i>)	215.92	4.52	0.04	0.10	3	209.92
Ψ (<i>openfor</i>), p (.)	215.93	4.53	0.04	0.10	3	209.93
Ψ (.), p (<i>highopen</i>)	215.98	4.58	0.04	0.10	3	209.98
Ψ (<i>disturbance</i>), p (.)	215.99	4.59	0.04	0.10	3	209.99
Ψ (<i>patchiness</i>), p (.)	216.04	4.64	0.04	0.10	3	210.04

Egyptian Vulture

Model	AIC	ΔAIC	AIC wt	Model Likelihood	K	-2log likelihood
Ψ (<i>L_drain+rau</i>), p (.)	216.54	0	0.89	1.00	4	208.54
Ψ (<i>L_drain</i>), p (.)	222.38	5.84	0.05	0.05	3	216.38
Ψ (<i>rau</i>), p (.)	223.2	6.66	0.03	0.04	3	217.2
Ψ (<i>barren</i>), p (.)	223.36	6.82	0.03	0.03	3	217.36
Ψ (.), p (.)	229.23	12.69	0.00	0.00	2	225.23
Ψ (<i>vill</i>), p (.)	229.55	13.01	0.00	0.00	3	223.55
Ψ (<i>rugged</i>), p (.)	230.83	14.29	0.00	0.00	3	224.83
Ψ (<i>openvsfor</i>), p (.)	231.03	14.49	0.00	0.00	3	225.03
Ψ (<i>disturb</i>), p (.)	231.12	14.58	0.00	0.00	3	225.12
Ψ (.), p (<i>highopen</i>)	231.23	14.69	0.00	0.00	3	225.23

Crested serpent eagle

Model	AIC	ΔAIC	AIC wt	Model Likelihood	K	-2log likelihood
$\Psi(L_drain + rugged), p(lowopen)$	230.44	0	0.80	1	5	220.44
$\Psi(L_drain), p(.)$	233.86	3.42	0.15	0.18	3	227.86
$\Psi(rugged), p(.)$	236.76	6.32	0.03	0.04	3	230.76
$\Psi(.), p(lowopen)$	238.56	8.12	0.01	0.02	3	232.56
$\Psi(disturbance), p(.)$	243.72	13.28	0.01	0.00	3	237.72
$\Psi(dist_vill), p(.)$	243.82	13.38	0.01	0.00	3	237.82
$\Psi(water), p(.)$	244.14	13.7	0.01	0.00	3	238.14
$\Psi(.), p(.)$	244.44	14	0.01	0.00	2	240.44
$\Psi(forestcover), p(.)$	246.4	15.96	0.01	0.00	3	240.4

Shaheen Falcon

Model	AIC	ΔAIC	AIC wt	Model Likelihood	K	-2*log likelihood
$\Psi(rau), p(.)$	52.11	0	0.72	1.00	3	46.11
$\Psi(rugged), p(.)$	56.16	4.05	0.09	0.13	3	50.16
$\Psi(disturbance), p(.)$	56.37	4.26	0.09	0.12	3	50.37
$\Psi(.), p(.)$	58.49	6.38	0.03	0.04	2	54.49
$\Psi(.), p(highopen)$	58.49	6.38	0.03	0.04	2	54.49
$\Psi(barren), p(.)$	59.82	7.71	0.02	0.02	3	53.82
$\Psi(.), p(modopen)$	60.11	8	0.01	0.02	2	56.11
$\Psi(patchiness), p(.)$	60.48	8.37	0.01	0.02	3	54.48
$\Psi(.), p(lowopen)$	61.61	9.5	0.01	0.01	2	57.61

Black-Shouldered kite

Model	AIC	ΔAIC	AIC wt	Model Likelihood	K	-2log likelihood
$\Psi(opeforest), p(.)$	54.22	0	0.91	1	3	48.22
$\Psi(.), p(.)$	61.81	7.59	0.02	0.02	2	57.81
$\Psi(L_drain), p(.)$	62.31	8.09	0.01	0.02	3	56.31
$\Psi(rau), p(.)$	63.32	9.1	0.01	0.01	3	57.32
$\Psi(disturbance), p(.)$	63.68	9.46	0.01	0.01	3	57.68
$\Psi(water), p(.)$	63.7	9.48	0.01	0.01	3	57.7
$\Psi(dist_vill), p(.)$	63.79	9.57	0.01	0.01	3	57.79
$\Psi(rugged), p(.)$	63.8	9.58	0.01	0.01	3	57.8
$\Psi(.), p(lowopen)$	63.81	9.59	0.01	0.01	3	57.81

Shikra

Model	AIC	Δ AIC	AIC wt	Model Likelihood	K	-2log likelihood
Ψ (dist_vill),p(.)	194.01	0	0.38	1	3	188.01
Ψ (dist_vill),p(midope)	194.57	0.56	0.29	0.76	4	186.57
Ψ (rugged),p(midopen)	195.82	1.81	0.15	0.40	4	187.82
Ψ (rugged),p(highopen)	197.62	3.61	0.06	0.16	4	189.62
Ψ (.), p(.)	197.94	3.93	0.05	0.14	2	193.94
Ψ (water),p(.)	199.36	5.35	0.02	0.07	3	193.36
Ψ (forest),p(.)	199.65	5.64	0.02	0.06	3	193.65
Ψ (dist_vill),p(highopen)	201	6.99	0.01	0.03	4	193
Ψ (.),p(highopen)	201.61	7.6	0.01	0.02	3	195.61
Ψ (.),p(midopen)	205.26	11.25	0.01	0.01	3	199.26

Appendix 6.Poster developed as a part of the project for sensitization and awareness of forest staff, tourists and students.



Photo: Shree Datta / Created by: Harish Khandelwal & Dhanraj Mishra

Rajaji National Park, situated in the Western Himalayan foothills, has 32 species of diurnal raptors or birds of prey. The high raptor diversity is due to the presence of varied habitats, such as dense Sal forests, seasonal rivers, mixed hill forests and grass-covered cliffs. This makes Rajaji landscape an important area for conservation of raptors, which play a crucial role in the ecosystem. By feeding on small animals like rodents they indirectly reduce damage to crops. Many raptors especially vultures prevent the spread of diseases by scavenging on dead animals. Rapid urbanization reduces the space and resources available to these birds, causing their decline.

हिमालय की तराई में स्थित, राजाजी राष्ट्रीय पार्क में 32 किस्म के दिवसीय शिकारी पक्षी पाये जाते हैं। पेटों की इस विविधता का मुख्य कारण यह है कि यहाँ अनेक प्रकार के वास स्थान मौजूद हैं जैसे कि खाल के घने जंगल, बरसाती नदियाँ, मिश्रित पहाड़ी वन और खड़ी चट्टानें। इसी कारण से राजाजी क्षेत्र शिकारी पक्षियों के संरक्षण के लिए महत्वपूर्ण है। पर्यावरणिक संतुलन में शिकारी पक्षियों की विशेष भूमिका है। पेटों वृद्धि के लिए भी लाभदायक हैं क्योंकि पक्षियों को नुकसान पहुँचाने वाले घूँटे आदि जीव इनका मुख्य आहार हैं। यह जान बहुत कम लोग जानते हैं कि पेटों मुख्यतः भिन्न वातावरण को स्वयं रखने में मदद करते हैं वृद्धि के बड़े हुए जानवरों को खतरा निवारणियों को फैलाने से रोकते हैं। तेजी से बढ़ते हुए शहरीकरण और मानवीय वृद्धि इन पक्षियों की संख्या में निरन्तर के प्रमुख कारण हैं।

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