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Evaluation of sambar and muntjak habitats using geostatistical modelling

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We report here the habitat evaluation for sambar (Cervus unicolor var. niger) and muntjak (Muntiacus muntjak var. vaginalis) in Ranikhet forests of Kumaon Himalaya using field survey, geostatistical analysis and geospatial tools. The geostatistical analysis was attempted at three levels: first, cases of animal sighting were taken (inclusive of mixed sightings) and subjected to principal components analysis to find the micro-habitat 'preference' by the respective animal. Secondly, cases where either sambar or muntjak were sighted were grouped into three categories, viz. pure sambar, pure muntjak and mixed and subsequently subjected to a discriminant function analysis to elicit the factors responsible for habitat use differentiation. Thirdly, a multiple binomial logistic regression was run on the dataset using cases of animal sighting used

as Boolean values as the dependent and six physical habitat variables, viz. forest density, drainage, aspect, slope, elevation and the human settlements variables as independents to derive the distribution of the respective species. Both the species showed highest preference for oak forests. Only 4.07% area was found highly suitable for sambar and 2.37% (200 ha) was so for muntjak. About 20% area in case of sambar and 10% in case of muntjak turned out to be moderately suitable to less suitable. The two species had only 0.35% (29.71 ha) habitat overlap. The sensitivity of the model was found to be 87.8% for sambar and 97.62% for muntjak. The study highlights synergistic use of field survey, geostatistical analysis and geospatial tools for evaluation of the sambar and muntjak habitats.

WILDLIFE includes non-domestic plants and animals and holds the key for the well being of humans. In recent years, much interest has been shown towards protection and conservation of wildlife at various levels. The work on conservation and management of wildlife is often hampered due to non-availability of good quality data on species, habitats and suitability of the habitats for different species. The problem is more acute in the developing world, where wildlife and biodiversity conservation is often subordinated to more pressing demands like hunger and poverty¹. Habitat evaluation is the first step towards meaningful wildlife conservation and management. Eva-

luation of wildlife habitats based on ecological principles is well established in USA in connection with environmental impact assessments, where the aim has been to ensure that appropriate consideration is given to wildlife in the development planning process. At the same time, there has been considerable pressure for the use of standardized procedures for habitat evaluation, both for economical as well as ecological reasons among various organizations and professionals. This pressure for standardization was one of the reasons why the Habitat Evaluation Procedure (HEP) was developed (initially by the U.S. Fish and Wildlife Service) for use in the evaluation of water and related land resources development projects². First developed in 1976, the HEP has been modified since then after detailed assessments and there are now

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many habitat evaluation models. The US Fish and Wildlife Service has developed as many as 157 habitat suitability models for large number of fish and other wildlife in the last 20 years. This is the most comprehensive database anywhere in the world³.

Geospatial technology for wildlife habitat evaluation

The geospatial technology, including remote sensing and geographic information system (GIS), holds the potential for timely and cost-effective assessment of natural resources. Remotely sensed data provides capabilities for synoptic, frequent, real-time assessment, monitoring and management of large areas. Earlier studies suggest a significant role for geospatial technology in wildlife conservation and management. Remotely sensed data have been used for habitat assessment of elk, Cervus canadensis⁴, and kangaroo, Macropus giganteus⁵. LANDSAT image classification, in combination with habitat model, helped in prediction of the nesting sites of American kestrel, Falco sparverius⁶. Visual LANDSAT image interpretation has been used as an effective tool in re-introduction programme of the white oryx, Oryx leucoryx⁷. An example of habitat evaluation, based on the ecology of the marten, Martes americana, was used by earlier workers⁸. Habitats of Indian one-horned rhino, Rhinoceros unicornis, wild buffalo, Bubalis bubalis, swamp deer, Cervus duvacelli, hog deer, Axis porcinus and Asian elephant, Elephus maximus have been evaluated using high resolution space photographs and LANDSAT multispectral data⁹.

Landscape variables were used to assess the habitat suitability for goral, Naemorhedus goral¹⁰. Vegetation, terrain and water parameters were converted into food and shelter values for assessment of the habitat suitability for sambar¹¹. Criteria-based spatial data integration for goral and sambar habitat evaluation have shown promising results 12-14. Remote sensing and GIS have been used for chinkara, Gezella bennetti habitat suitability analysis in Rajasthan¹⁵. GIS has assumed a central role over the years in numerous species-specific applications but there is more scope for GIS in modelling species assemblages, scale-dependent habitat preferences, geographical fragmentation of populations, habitat heterogeneity and ecological integrity ^{16,17}. By now, it is well established that geospatial tools are indispensable for habitat evaluation. Some authors have reported on cost-coverage analysis of remote sensing and GIS-based habitat evaluations ^{18,19}.

The fragmentation, degradation and depletion of natural habitats have created an adverse impact on the populations of faunal species in general, and the ungulates in particular in Kumaon region of western Himalaya. The changes in the landuse pattern here have brought about the decline and total disappearance of large and mediumsized mammalian fauna from many sites²⁰. In a recent study on the status and distribution of deer species in

Kumaon Himalaya, the researchers could record sambar and muntjak only from 14 sites. This was attributed to high human pressure and habitat shrinkage²¹. Hence, we took up evaluation of habitats of sambar and muntjak using geostistical and geospatial tools. Such a study has not been carried out in this region.

Study area

The study was carried in the Chaubatia Reserve Forest (area 8428 ha) located close to Ranikhet town of Almora district in Kumaon Himalaya (79°24′-79°30′E and 29°35′-29°40′N). Figure 1 shows the location of the study area. Forests dominate the landscape in the study area. The forest type of the study area has been broadly classified as Himalayan Moist Temperate by Champion and Seth²². The oak forest in the study area is regarded as the climax vegetation. Five major forest types are found in Ranikhet: (i) oak forest, (ii) oak-pine forest, (iii) chirpine forest, (iv) pure deodar and (v) mixed deodar forests. The study area provides diverse and favourable habitats for a wide range of wild animals. The most notable species are: common leopard (Panthera pardus), red fox (Vulpes vulpes), Himalayan yellow-throated marten (Martes flavigula), hanuman langur (Semnopethicus entellus), rhesus macaque (Macaca mulatta), sambar (Cervus unicolor), muntjak (Muntiacus muntjak) and Kashmir flying squirrel (Hylopetes fimbriatus)²³.

Four broad soil categories, viz. red loam, brown forest soil, loam and meadow soil have been reported from Ranikhet²⁴. Soil rich in organic matter on northern slopes is highly suitable for oak. The soil is poor, shallow and dry in pine forest, especially in heavily grazed areas and on southern aspects. Mica and chlorite are the dominant materials in the clay and silt fractions. The rocks are mainly schistose with mica²⁵. Winter, summer and monsoon seasons are distinct at Ranikhet. The winter season commences in October and continues up to March (temperature 1° to 25°C). The summer season extends from April to June (temperature 12° to 38°C). May and June are warm and humid. Monsoon sets in July and persists till the end of September. The post-monsoon weather is usually fair²⁶.

Kumaon region is spread over 21,073 km² and had extensive tracts of natural forests until a few centuries back. Though there was no scientific exploration to document the extent of these natural forests and the faunal populations, the old records of naturalists and hunters illustrate floral and faunal richness in the region. Extensive areas under natural forests were cleared up to late forties either for valuable timber or for planting commercially viable species. Large tracts of oak forests were cleared for raising the plantations of chirpine to ensure the regular supply of timber. This trend continued even after India's independence, until the Forest Conservation Act came into being in 1980. During post-independence era, Kumaon

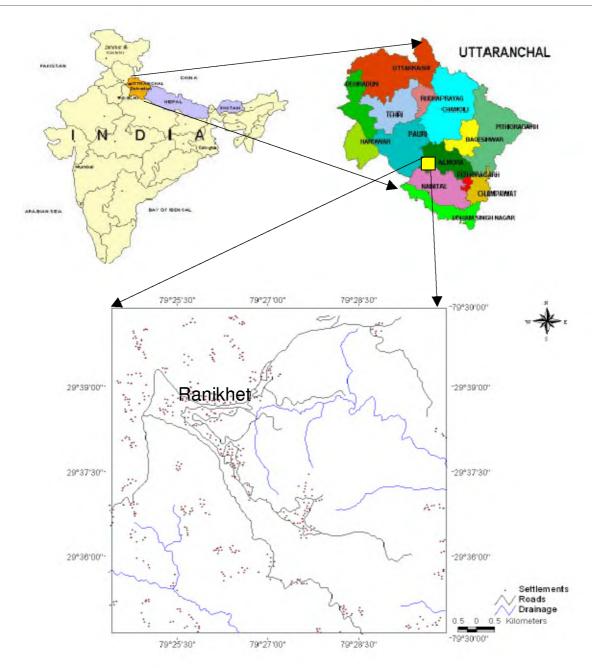


Figure 1. Location of the study area in India.

Himalaya witnessed large-scale changes in its landuse pattern due to rapid urbanization and agricultural expansion. This has depleted the forest cover and degraded the land-scape. Much of the low and middle altitude oak forests have been either replaced with chirpine or lost to terrace cultivation. The existing patches, including plantations, are highly fragmented and degraded. The study area represents a cross-section of habitat types in Kumaon Himalaya.

Materials and methods

The study was carried out in three phases. The first phase included field survey to collect information on habitat use

by sambar and muntjak. During the second phase, a database was created and statistical analysis of the field data was carried out. The third phase work included geospatial modelling.

Field survey

An intensive field survey was carried out for a period of two months (from 1 October to 30 November 2000) to analyse the habitat use by sambar and muntjak. Presence of pellet groups was taken as indirect evidence of habitat use for both the species²⁷. Twelve transects were laid in different habitat types -2 in oak, 2 in oak mixed, 4 in

oak-pine, 2 in pine and 2 in deodar. In each transect, pellet groups were counted in 10 m radius plots. A total of 96 plots (eight in each transect) were sampled. The density, diversity and the richness of the tree species were assessed using the same 10 m radius circular plots. The canopy cover was measured using a gridded mirror of 25 cm × 25 cm in four different directions inside the circular plot. Shrub richness and height were measured from a 3 m-radius circular plot. Shrub cover was measured in five equal density classes of 0-20%, 20-40%, 40-60%, 60-80% and 80-100%. The grass and herbs were quantified from four plots of $50 \text{ cm} \times 50 \text{ cm}$ at four different locations inside the circular plot. A tape was laid on the ground in four directions and intercepting features of ground cover such as herbs, grasses, shrubs, litter, rock outcrops were recorded. At each sample plot, location, slope, aspect, elevation, evidence of fire, number of cut/ lopped trees and cattle dung were also recorded. The number of pellet groups for each species in each plot was used to calculate pellet group density per ha. Two sets of field data were made: one set was used to derive the habitat use information through statistical analysis and the other set for mapping accuracy and model sensitivity determination.

Database creation

The standard IRS-1C LISS-III false color composite of 7 January 2001 (Figure 2) was used to prepare the habitat (Figure 3) and canopy density maps (Figure 4) through on-screen visual interpretation. Four canopy density classes, viz. <10% (non-forest), 10–40% (open), 40–70% (medium dense) and >70% (dense) could be interpreted from remotely sensed data. Image elements like tone, texture, shape, size, shadow, location and association were used for this purpose. Forest type and density maps were evaluated for classification accuracy using second set of field data. The slope, aspect and elevation maps were generated from topographic maps through scanning and digitization using ArcView. Disturbance features, viz. roads and settlements were also taken from topographic maps. Continuous surfaces of distances from water bodies and settlements were generated for proximity analysis. All the input map layers were co-registered with sub-pixel accuracy.

Geostatistical analysis

The field data were statistically analysed to understand the habitat use pattern by the two ungulate species. This included Principal Component Analysis (PCA), Discriminant Function Analysis (DFA) and Binomial Multiple Logistic Regression (BMLR).

PCA: All cases were first filtered on the basis of the sighting of individual species and the PCA (correlation coefficients, varimax rotation) was run on the dataset.

Variables showing very low loadings on the rotated component matrices were successively dropped to reduce the noise in the dataset and ultimately 13 variables were seen to explain maximum variation (75.96%, 4 factors: muntjak, 74.45%, 4 factors; sambar) and were analysed in conjunction with DFA to arrive at patterns of habitat differentiation and preference by the two species.

DFA: Discriminant function analysis was used to investigate the habitat differentiation by the species. It was observed that as only two species were involved, the DFA would produce only one function. This would limit the analysis solely to the magnitudes of the discriminant functions. Also, this would entail making the relative location of the two species vis-à-vis the functions difficult. To work around this problem, the cases were grouped and recoded into three classes, two for pure sightings in each species and one for mixed sightings (Df. 30; sambar, Df. 8; muntjak, Df. 20; mixed), and the three recoded cases used as input for the DFA (Df. 58, 27 variables). The relative location of the group centroids (Figure 5) for the two pure-case variables was then analysed against the derived (now two) discriminant functions to conclude the 'exclusive' habitat usage between the two species. All the variables were entered into the analysis to elicit differences between the responses of the DFA to the various measured landscape variables. The DFA resulted in the correct classification of 79.3% of the cases and showed canonical correlation coefficients of 0.737 and 0.529 for the first and the second function respectively. The significance levels obtained, however, were not impressive as there was a big difference between the number of variables included and the number of valid cases.

BMLR: Six variables in the dataset were seen as suitable proxies for the satellite-derived data and were used as independents in the analysis. Two variables, among the six considered, had been previously recoded and were thus specified as categorical. Individual cases of animal sightings were considered as Boolean and a binomial multiple logistic regression was run. Outliers in the dataset were detected using studentized standard deviations of residuals greater than specified cut intervals (± 2.0 for muntjak and \pm 1.8 for sambar). The cases producing the outliers were successively screened until 85% (± 125) cases remained within the dataset. Overall classification accuracies of 97.62% and 87.80% were obtained at a 0.4 probability cut-off for muntjak (Df 126, R²: 0.886 (Nagelkerke pseudo R^2)) and sambar (Df 123, R^2 : 0.773) respectively. The coefficients thus obtained were then used for subsequent raster analysis (distribution mapping) on ILWIS 3.1 software. The result was Logit transformed $[P = \{\exp(a +$ BX...)/(1 + (exp(a + BX...)))}] to obtain absolute habitat occupancy map. For obtaining the habitat preferences the output was re-scaled to a range of 1-10 and was subjectted to an exponential transformation to produce the most

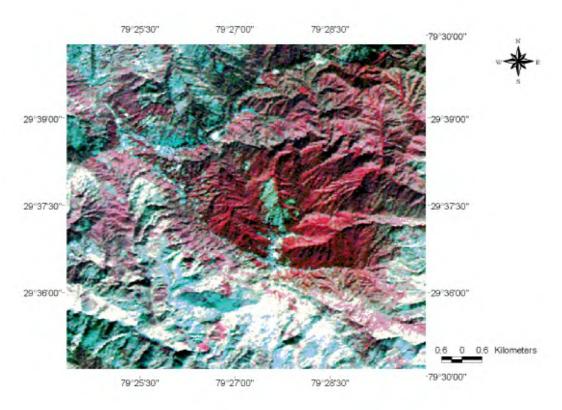


Figure 2. IRS LISS-III false colour composite of the study area.

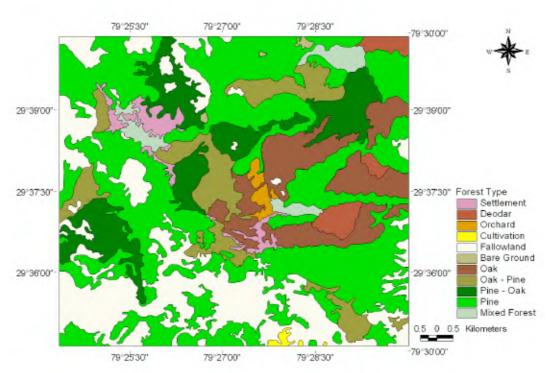


Figure 3. Habitat map generated from satellite imagery.

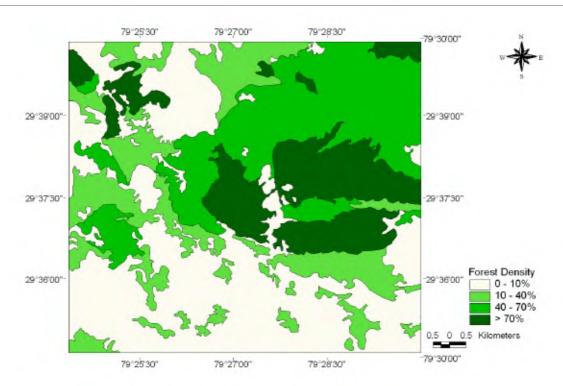


Figure 4. Forest density in the study area.

conservative estimates possible. The transformed output was then equal-interval sliced into *not suitable*, *moderately suitable*, *suitable* and *highly suitable* categories. The models derived were:

Sambar: HIS = {exp(0.0309* ALTITUDE + 24.8315* TC100 - 0.0175* DISTW + 0.0092* DISTHH + ASPECT* (Coeff.) + SLOPE* (Coeff.) -78.8907)/(1 + (exp(0.0309* ALTITUDE + 24.8315* TC100 - 0.0175* DISTW + 0.0092* DISTHH + ASPECT* (Coeff.) + SLOPE* (Coeff.) - 78.8907))}

Coefficients	(sambar
Cocifficients	(Samuar

Aspect	Coefficients
ASPECT(1)	-14.2555
ASPECT(2)	3.9879
ASPECT(3)	-0.9184
ASPECT(4)	-1.4369
ASPECT(5)	0.0607
ASPECT(6)	-6.7155
ASPECT(7)	-2.5471
ASPECT(8)	0.0000
Slope	
SLOPE(1)	-1.6300
SLOPE(2)	0.2705
SLOPE(3)	0.0000

Muntjak: HSI = {exp(0.2527* ALTITUDE + 22.615* TC100 - 0.0287* DISTW - 0.0002* DISTHH + ASPECT* (Coeff.) + SLOPE* (Coeff.) - 543.035)/(1 + exp(0.2527*

ALTITUDE + 22.615* TC100 - 0.0287* DISTW - 0.0002* DISTHH + ASPECT* (Coeff.) + SLOPE* (Coeff.) - 543.035))}

Coefficients	(muntiak)
Cocifficients	(munijak)

	\ 3 /
Aspect	Coefficients
ASPECT(1)	2.6509
ASPECT(2)	85.4775
ASPECT(3)	-0.8746
ASPECT(4)	19.3989
ASPECT(5)	85.7738
ASPECT(6)	21.4075
ASPECT(7)	45.8798
ASPECT(8)	0.0000
Slope	
SLOPE(1)	-55.3976
SLOPE(2)	-19.2510
SLOPE(3)	0.0000

Results

Table 1 gives details of the different habitat types in the study area. Chirpine was the dominant vegetation in the area followed by pine-oak and the oak. Among the nonforest categories, fallow land was most prevalent. Forest density varies with respect to environmental gradients in the study area. About 17.04% forests were classified as dense forest (canopy density >70%), 23.85% as medium dense (density 40–70%), 19.20% as open (density 10–

40%) and remaining 40.00% as < 10% (Figure 4). The area under habitation was 1.80 km² (2.05% of the total study area).

A study of the factor loadings of all variables on the components (Tables 2 and 3) showed the following: The Principal Component 1 for sambar (Var. 21.01%) indicated an affinity towards large distances from human settlements and high tree density coupled with low shrub

Table 1. Area under different habitat types

	~ 1	
Forest type	Area (ha)	Area (%)
Pine	3650	41.48
Oak	880	10.00
Deodar	185	2.10
Oak-pine	750	8.52
Pine-oak	1000	11.36
Mixed	205	2.33
Orchard	100	1.14
Cultivation	30	0.34
Fallow land	1800	20.45
Habitation	180	2.05
Playground	20	0.23

Table 2. Rotated principal component matrix (sambar)

Variable	1	2	3	4
Altitude	-5.14E-02	-7.70E-02	-8.11E-02	0.853
Shrub cover	-0.596	0.365	-5.02E-02	-0.279
Grass cover	8.61E-03	0.708	1.23E-02	-0.333
Trees logged	0.242	0.668	3.88E-02	0.113
Dist. to settlements	0.712	-0.194	-0.189	0.164
Tree numbers	0.901	0.263	6.47E-02	-0.14
Tree density	0.902	0.263	6.31E-02	-0.139
Herb numbers	-4.40E-03	8.29E-02	0.962	-0.152
Herb density	-4.40E-03	8.29E-02	0.962	-0.152
Herb diversity	-0.409	-0.308	0.245	-0.63
Grass numbers	-5.06E-02	0.734	0.547	0.155
Grass density	-5.06E-02	0.734	0.547	0.155
Grass cover	-0.102	0.502	-6.53E-02	0.441

Table 3. Rotated principal component matrix (muntjak)

				-
Variable	1	2	3	4
ALT_L	0.234	-0.352	-0.695	-0.166
SCAC	0.131	-0.242	0.788	2.69E-04
GC_AC	0.395	0.344	0.617	3.12E-02
TL_L	0.586	0.453	0.156	-2.05E-02
DHH_L	-0.289	0.235	-0.555	-0.163
TN_L	1.87E-02	0.941	-5.25E-02	0.238
TD_L	1.63E-02	0.941	-5.48E-02	0.235
HN_L	0.191	0.233	0.145	0.919
HD_L	0.191	0.233	0.145	0.919
HDV_L	-0.478	1.68E-02	0.619	0.401
GN_L	0.837	7.45E-02	0.139	0.345
GD_L	0.837	7.45E-02	0.139	0.345
GAC	0.705	-0.143	-7.05E-02	-3.09E-02

cover; Component 2 (Var. 20.76%) showed high loadings on ground cover, grass cover and density and trees logged; Component 3 (Var. 19.74%) showed a preference for herb density and the last component (Var. 12.93%) showed a gradient of high altitude and decreasing herb diversity. The Principal Component 2 for muntjak (Var.

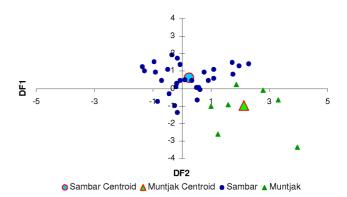


Figure 5. Habitat preference of sambar and muntjak.

Table 4. DFA structure matrix

Variable	1	2
GRAC (Grass density)	-0.260*	-0.106
GC_AC (Grass cover)	-0.245*	-0.108
ALT_L (Altitude)	0.212*	0.101
HC_AC (Herb cover)	-0.205*	0.088
GDV_L (Grass diversity)	-0.190*	-0.029
R_AC (Rocky area)	0.187*	-0.025
GN_L (Grass number)	-0.187*	-0.131
GD_L(a) (Grass height)	-0.187*	-0.131
SH_L (Shrub height)	0.181*	-0.144
TCUTL (Tree cut)	-0.165*	0.111
GR_L (Grass richness)	-0.142*	0.002
SDV_L (Shrub diversity)	0.092*	0.05
HDV_L (Herb diversity)	0.088*	-0.035
SN_L (Shrub number)	0.060*	-0.021
SD_L(a) (Shrub density)	0.059*	-0.021
HR_L (Herb richness)	0.272	-0.361*
CD_L (Cattle dung)	0.133	0.236*
SR_L (Shrub richness)	0.159	0.226*
TDV_L (Tree diversity)	0.082	0.208*
TN_L (Tree number)	-0.197	0.205*
TD_L(a) (Tree density)	-0.194	0.204*
L_AC (Litter cover)	0.158	0.191*
HN_L (Herb number)	-0.175	0.191*
HD_L(a) (Herb density)	-0.175	0.191*
DHH_L (Dist. to settlement)	-0.075	0.161*
HAC (Herb cover)	-0.059	-0.128*
TRH_L (Tree height)	0.029	0.120*
TL_L (Tree logged)	-0.074	-0.114*
DW_L (Distance to water)	0.079	-0.082*
BG_AC (Bare ground)	-0.021	0.071*
TCAC (Tree cover)	0	-0.061*
WS_AC (Weathered stone)	0.052	-0.053*
SCAC (Shrub cover)	0.012	-0.038*

^{*}Indicates highest correlations in the group.

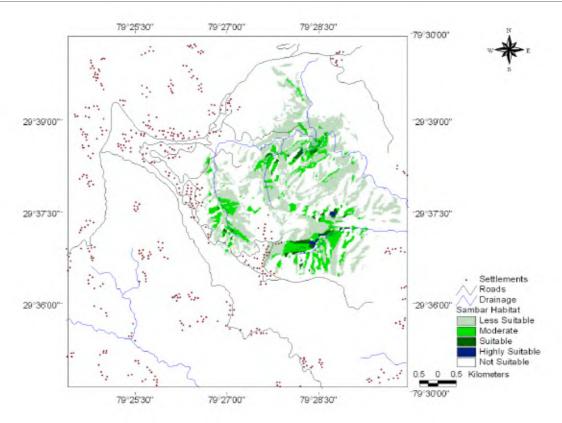


Figure 6. Habitat suitability for sambar.

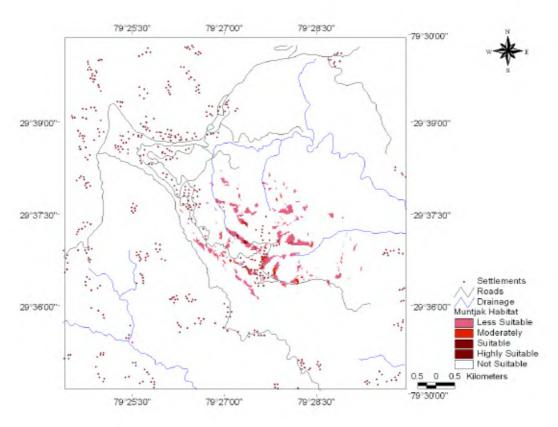


Figure 7. Habitat suitability for muntjak.

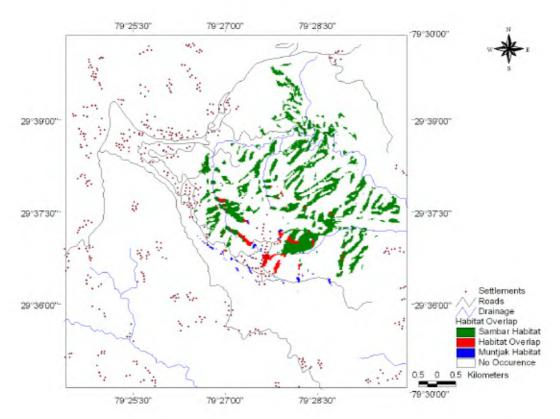


Figure 8. Habitat overlap for sambar and muntjak.

21.96%) indicated an affinity towards high grass density and diversity probably as a resultant of tree logging; Component 2 (Var. 19.01%) shows a preference towards regions with high tree density; Component 3 (Var. 17.63%) indicates a gradient of high shrub cover, ground cover and herb diversity coupled with decreasing altitude; Component 4 (Var. 17.35%) shows high loadings on high herb density (Tables 2 and 3).

The analysis indicates a primary preference of sambar to high tree and herb density but low shrub cover whereas muntjak seems to prefer regions of high grass density on the same scale. Sambar prefers sites that score low in terms of direct human disturbance and similar conclusions can be drawn for muntjak. The analysis indicates an indifference of both the species towards logging activities when good grass growth is resultant. The analysis also indicates preference of sambar for higher altitudes coupled with a relative indifference for herb diversity whereas muntjak is seen preferring relatively lower altitudes with higher herb density and diversity.

A study of the DFA structure matrix (Table 4) and the relative location of the species centroids against the two extracted functions can be seen to indicate the occupancy of muntjak higher along the gradient, indicated by the discriminant function 1 (DF1), whereas the occupancy of sambar along the gradient is indicated by the discriminant function 2 (DF2). DF1 can be seen as an indicator of a

gradient of decreasing grass density and diversity with increasing altitude. It also indicates high shrub density, diversity and height and less human disturbance marked by tree cutting. DF2 indicates high tree cover and diversity coupled with low direct human disturbance in terms of distances from settlements. It, however, also indicates disturbance due to cattle grazing and tree lopping. Muntjak can be seen occupying the higher sector of DF1 and sambar the higher sector of DF2. The location of the sambar centroids (Figure 5) nearer the central value also indicates the higher adaptability of the species to diverse situations as compared to the limited niche of the muntjak.

Interpreting the DFA in conjunction with the results of the habitat preferences obtained from the PCA, it can be seen that sambar and muntjak habitat preferences indicate dissimilarities in both the analyses; there is a marked affinity of sambar towards higher altitudinal regions with high tree density whereas muntjak shows preferences towards lower altitudes with better grass growth. Both the species have shown a negative response towards direct human interference but can be seen to be more tolerant with indirect human interference impacts such as cattle grazing or tree lopping. The pattern can also be interpreted as an adaptation of the sambar towards direct and indirect changes in its habitat in the landscape, whereas muntjak continues to restrict its range to a very limited spectrum

of landscape variables. Figures 6 and 7 depict the habitat suitability (occupancy) for sambar and muntjak in the study area. Habitat preference is shown in Table 5. A total of 343 ha (4.07%) habitat was found highly suitable to suitable for sambar. For muntjak, this category worked out to be 200 ha (2.37%). Another 19.82% area in case of sambar and 10.23 in case of muntjak was found moderately suitable to less suitable (Tables 6 and 7). The area of habitat overlap was found to be 29.71 ha, which constituted only 0.35% of the total study area (Figure 8). Field-based experiences corroborated the result of the cross-tabulation of the absolute habitat occupancy by the animals. The habitat suitability information was noted to be 87.8 and 97.62% accurate for sambar and muntjak respectively.

Discussion and conclusions

Habitat suitability analysis is considered important for introduction, rehabilitation and *ex-situ* conservation of species and their habitats. Habitat models are based on the relationship between the animal and environment. Such models are normally animal-centric and usually consistent

Table 5. Habitat preferences of sambar and muntjak

Sambar		Muntjak		
Habitat type	Area (ha)	Area (%)	Area (ha)	Area (%)
Oak	70.85	28.58	7.95	73.47
Pine	66.10	26.67	0.39	3.57
Oak-pine	36.00	14.52	0.55	5.10
Deodar	32.85	13.25	0.22	2.04
Pine-oak	25.29	10.20	0.00	0.00
Mixed forest	14.68	5.93	1.33	12.24
Orchard	1.98	0.80	0.28	2.55
Fallow	0.11	0.04	0.11	1.02

Table 6. Habitat suitability for sambar and muntjak

	Sambar		Muntjak	
Habitat suitability	Area (ha)	Area (%)	Area (ha)	Area (%)
Not suitable	6414	76.10	7366	87.40
Less suitable	1080	12.81	572	6.79
Moderately suitable	591	7.01	290	3.44
Suitable	258	3.06	150	1.78
Highly suitable	85	1.01	50	0.59

Table 7. Habitat overlap of sambar and muntjak

Habitat overlap	Area (ha)	Area (%)
Sambar not expected * muntjak not expected	7975.15	94.63
Sambar expected * muntjak not expected	413.85	4.91
Sambar expected * muntjak expected	29.71	0.35
Sambar not expected * muntjak expected	9.27	0.11

with the data needs for planning. Maximum number of pellet groups of both the species was recorded in the areas away from human habitations and having least disturbance, which means that both sambar and muntjak avoid human disturbance. The low overall suitability of Chaubatia forest for sambar (23.89%) and muntjak (12.60%) can be attributed to disturbance in their habitat. Hence, human activities in the forests need to be minimized for any effective conservation of these two species. The model sensitivity worked out to be 87.8% for sambar and 97.62% for muntjak, which implies that the model was sensitive to meet the objectives of this study. The low value of the habitat overlap of two species indicates their contrasting habitat preferences. As obvious from this and other studies²⁸, sambar prefers hilly areas with high tree density while muntjak prefers plain areas. Because of increasing disturbance, the wildlife habitats in Kumaon region are shrinking²¹. If the situation is not tackled, a time may come when ungulates, which play important role in vegetation dynamics and form a connecting link in the food chain, will disappear from these forests. Hence, necessary steps should be taken to conserve the forests. As evident from this study, the geospatial technologies – remote sensing and GIS, can play a very important role in the wildlife habitat suitability assessment. The former provides frequent coverage and unbiased data while the latter facilitates in database generation and spatial analysis.

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