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Research Article

DETERMINANTS OF DISTRIBUTION OF LARGE MAMMALS IN SETI RIVER BASIN, TANAHUN DISTRICT OF WESTERN NEPAL

Jagan Nath Adhikari[1,2], Bishnu Prasad Bhattarai[1*], Tej Bahadur Thapa[1]

[1]Central Department of Zoology, Tribhuvan University, Kirtipur, Kathmandu, Nepal
[2]Department of Zoology, Birendra Multiple Campus, Tribhuvan University, Chitwan
**Corresponding author: bpbhattarai@cdztu.edu.np; bhattaraibp@gmail.com*

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ABSTRACT

Forest landscape in Seti River basin of Western Nepal is not conserved within the protected area network. Wildlife habitats in Seti River basin are more vulnerable due to high anthropogenic disturbance and habitat fragmentation. Present study mainly focused to evaluate the major factors that determine the distribution of large mammals in Seti River basin by walking through 34 line transects that covered a total of 59.89 km. The distribution of large mammals was greatly affected by habitat types, human disturbances, topography and altitude. Himalayan gorals were recorded in the steep grass covered areas where as Muntjacs were found in most of the habitats and slopes. There was low occurrence of all species nearer to the settlements and roads. Besides, water sources played a vital role in distribution of wildlife, as there were more occurrences of signs of large mammals nearby water resources. In the study area, community forests played a major role in the conservation of viable population of large mammals. However, habitat fragmentation due to scattered human settlements and degradation of foraging grounds such as grasslands by succession and invasion of alien plant species added more threats to the survival of large mammals. Therefore, such situation can be improved through the protection of connecting forest patches and scientific management of forests and grasslands.

Keywords: Himalayan Goral, Human disturbance, Muntjac, Sal forest, Topography.

INTRODUCTION

Nepal, a biodiversity rich Himalayan country is situated in the central part of the world's top 20 global biodiversity hotspots, the Himalayas (CI 2004) with six biomes and twelve out of 867 terrestrial eco–regions of the world (Dinerstein *et al.* 2007, Shrestha *et al.* 2010). Nepal has diverse geological and geographical structures and has thousands of rivers flowing from north to south forming gorges, river basins and valleys (Paudel *et al*. 2012). A diverse geographic structure has maximum relief, steep slope and rugged terrain (Hegan 1998). Unique geographic position and variation in the altitude and climate of Nepal supports diverse flora and fauna. The human settlements are scattered in the mid-hill of Nepal that fragments the natural forest habitats of wildlife.

Fragmentation and loss of habitat are recognized as the greatest existing threats to biodiversity (Fahrig 2003, Hilty *et al*. 2006). Cumulative researches indicate that habitat loss has consistent negative impact on biodiversity (Closset-Kopp *et al.* 2016, Shrestha 2004). Human–caused habitat fragmentation precipitates biodiversity decline because it destroys species, disrupts community interactions, and interrupts evolutionary processes (Ehrlich & Ehrlich 1981, Erb *et al.* 2012). Habitat quality in fragments may be a more important determinant of assemblages of mammals (Delciellos *et al*. 2015). Global extinction of species, driven by anthropogenic factors, is occurring at an unprecedented rate (Bloom *et al.* 2005, Bendix *et al.* 2017, Karanth & Kudalkar 2017). Among more than 83000 species evaluated, 29 % are categorized as threatened (IUCN 2019). Large terrestrial mammals are among the most threatened taxa in the world, with 25 % of species facing extinction and 50 % with declining populations (Ceballos 2007). Furthermore, mammals of South Asia such as Bengal tiger, snow leopard, greater one horned rhinoceros, Asiatic elephant are among the most endangered (Bhattarai & Kindlmann 2012, Karanth *et al.* 2010).

Twenty-five species of mammals in Nepal are globally threatened and 17 are near threatened (Amin *et al*. 2018, IUCN 2019). Similarly, 49 species were evaluated as nationally threatened (nine critically endangered species, 26 endangered species and 14 vulnerable species). Likewise, seven species were listed in near threatened and 83 species were listed in data deficient (Amin *et al.* 2018). Correspondingly, 73 mammals have been listed in the CITES Appendices (32 in Appendix I, 14 in Appendix II and 27 in Appendix III) (Jnawali *et al.* 2011, DNPWC 2018).

Conservation of biodiversity through protected areas (PAs) has been weaker on several aspects, because they are too small and isolated to maintain viable populations of many species (Naughton-Treves *et al.* 2005). Possibility study of linking habitats in human-dominated mid-hill landscape as in Tanahun district is highly applicable for habitat extension of wildlife in isolated protected areas (Cooke *et al.* 2018) such as Chitwan National Park. Hence, this study mainly focused to evaluate factors determining distribution of large mammals in Seti River basin. The main objective of this study was to obtain a better understanding of how forest types, anthropogenic activities (disturbance) and topographic structures influenced the distribution of mammals in human dominated landscapes.

MATERIALS AND METHODS

Study area

Study area encompasses most parts of Seti River basin including the Devghat, Bandipur, Abukhairani Rural Municipalities and Byas Municipality of Tanahun district. The study area covers an area of 429.47 km^2 (Fig. 1). More than 50 community forests have been established in this area including Sita Ban, Rani Ban, Madhu Ban, Deuti, Kalika, Sirichuli, Chhimkeswari, Madan Danda, Dharampani, Siddhathani and Dagara Manakamana. Wildlife habitat in the study area is mainly covered by forest along with grassland, bushy area, crop land and settlements. Sal is the most dominant species including Saj, Simal and Khayer. The diversity of the forest is more along the Trisuli and Seti River side (Fig. 1c). Devghat area is mainly dominated by Sal forest. Most parts of study area possess mixed type of forests- Sal (*Shorea robusta)* forest; Sal (*Shorea robusta)*- Karma (*Adina cordifolia)* forest; Sal (*Shorea robusta)*-Saj (*Terminalia alata*) forest; Simal (*Bombax ceiba)*forest; Mixed hardwood forest-Dhairo (*Woodfordia fruticose*), Kafal (*Myrica esculenta)*, Kutmero (*Litsea monopetala*) and Amaro (*Spondias pinnata)*; Riverine forest- Khayer (*Acacia catechu*), Veller (*Trewia nudiflora*) and Padke (*Litsea doshia*) (WWF 2013). Most of the forests of this area have been managed under the jurisdiction of community forestry.

The majority of the forest areas are fragmented by cropland and human settlements (Adhikari *et al.* 2018, unpublished data). The model species used in the study were large mammals (>10 kg of average body weight) such as common leopard (*Panthera pardus* Linnaeus, 1758), Himalayan black bear (*Ursus thibetanus* Cuvier, 1823), Chital (*Axis axis* Erxleben, 1777), Northern red muntjac (*Muntiacus vaginalis* Boddaert, 1785), Himalayan goral (*Naemorhedus goral* Hardwicke, 1825), wild boar (*Sus scrofa* Linnaeus, 1758) and common langur- *Semnopithecus* spp. (Dufresne, 1797).

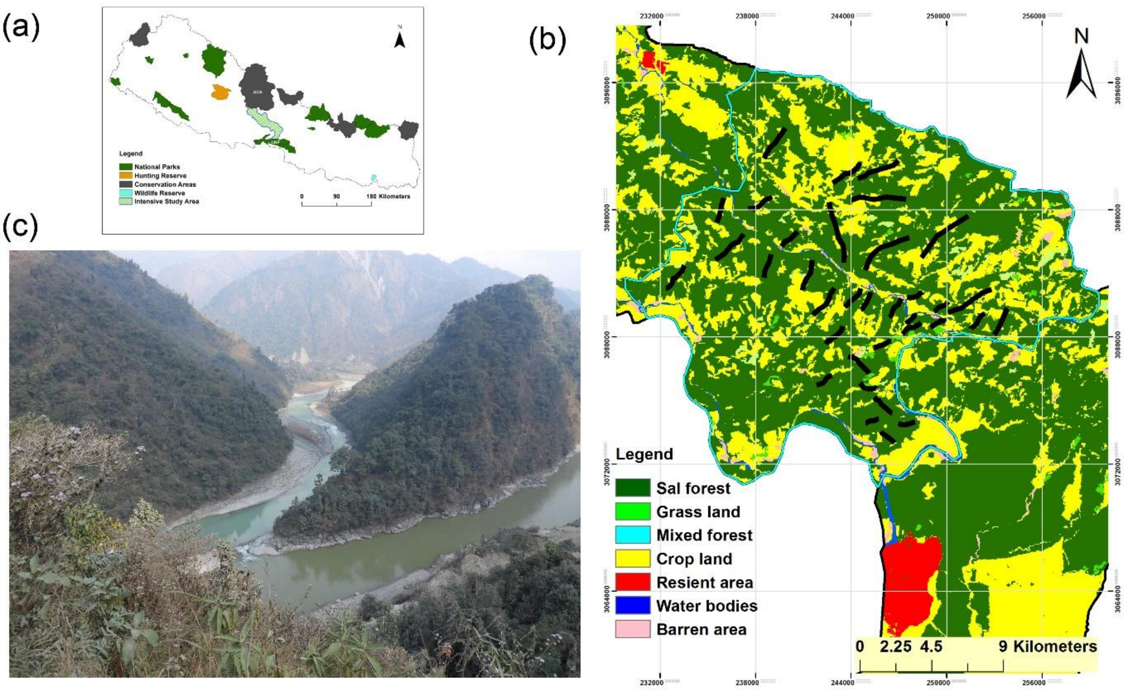

Fig. 1. (a) Map showing the intensive study area that links two biodiversity significant areas of CNP and ACA. (b) Intensive study area (lower part of Tanahun district) with transects (Forest= all types of forest including Sal, Simal, Saj, Pinus, Chilaune, Katus, Shrubland= bushy area, Grassland= grass covered area, Agriculture area= crop land or cultivated area, Barren area= arid area has no any vegetation, sand and gravel covered area, Water body= rivers, streams, ponds, lakes and water locked area, Built-up area= city area) (c) Confluence of Seti and Trishuli Rivers in Gaighat, Tanahun district (Source: Department of Survey)

Methods

Transect layout

A total length of transects was estimated as suggested by Burnham *et al.* (1980) and Morrison and Kennedy (1989). The major habitats, slopes and patch size were determined during pilot survey and with the help of topographic maps developed by Department of Survey, Government of Nepal. The size and length of transects varied according to the habitat types and size of the forest patches, slopes, aspects, settlements and croplands. We followed the Seti River basin and laid 34 line transects with total linear distance of 59.89 km (mean= 1.76, SE= 0.13, range= 0.89-3.66 km) (Fig. 1b).

Presence/ absence survey of mammals

Presence/absence data were collected using transects survey (Silveira *et al.* 2003). The signs left by the animals such as pugmarks/foot print, dung/dropping/scat and other signs (scrap, scent marks etc.) are a reliable indicator of animal presence and have frequently been used for estimating abundance (Bhattarai & Kindlmann 2012). The signs left by the large mammals, such as faecal matter, scratch, scrap marks were observed at regular interval of 100m distance, by developing the quadrates of 10×10 m^2 to determine the presence or absence. Besides these, the ungulates were surveyed by direct observation method. The group size of the ungulates was recorded with their age and sex composition. The collected data were used to estimate the presence/absence, abundance and distribution pattern.

Topographic, habitats and disturbance data collection

Topography and habitat variable was collected along the same transects where signs of large mammals were found (Table 1). The indicators of anthropogenic disturbances such as livestock grazing, firewood/timber collection, fodder collection, road construction and distance to trails/roads/settlements were explored in the study area. The signs of the human disturbances were reordered within the 10×10 m^2 quadrates at the interval of 100 m along the transects. These data were categorized to measure the habitat disturbance status (HDS) (Blom *et al*. 2005, Bhattarai & Kindlmann 2012). In each sampling points, following information was recorded.

- **Species variables**
  a. All ungulate and primate species seen,
  b. Their group size based on direct observation and
  c. Signs of the presence of predators (tiger and leopard)
- **Environmental variables:** Habitat, topographic and disturbance variables (anthropogenic) are some examples of the environmental variables as pointed out below.

Habitat variables

a. Types of habitats such as Sal forest, grassland, bushy areas associated with grassland, *Pinus* forest, *Alnus* forest, *Schima-Castanopsis* forest, Sal-Saj forest etc.
b. Forest cover (dense- greater than 50 % canopy cover or moderately dense- 10-50 % canopy cover or open- less than 10 % canopy cover) and
c. Distance to the nearest waterhole (Euclidean distance measured from sampling point to the nearest waterhole)

Topographic variables

a. Slope (plane: zero degree, gentle slope 1° to 20°, slope 20° to 45°, steep more than 45°)
b. Altitude

Disturbance variables (anthropogenic)

a. People's presence based on the numbers of lopped and logged trees and sites used for harvesting grass
b. Number of tourists present
c. Number of vehicle present
d. Livestock presence based on the number of dungs
e. Distance from the road/settlements

Habitat disturbance status (HDS) was calculated by using all the human disturbance variables as listed above excluding distance to road and settlements. The human presence indicators (numbers of lopped trees, logged trees, sites used for fodder collection) and livestock (number of dungs of livestock) presence were combined and scored in ordinal scale of 1 to 5 based on total number of signs of disturbance as 1, 2, 3, 4 or 5 indicating a very low, low, moderate, high or very high level of habitat disturbance status (HDS), respectively (Table 1). A 30 m resolution Digital Elevation Model (DEM) was downloaded from the U.S. Geological Survey (USGS) (https://earthexplorer.usgs.gov) and calculated slope from the DEM raster map and categorized the slope as plane: zero degree, gentle slope 1° to 20°, slope 20° to 45°, steep more than 45°.

Data analysis

Canonical correspondence analysis (CCA) was used for each species and then compared with the associations of species with environmental variables, topography, disturbance variables, because the behaviour in terms of habitat preference and tolerance to disturbance for different species differ significantly (Leps & Similaur 2003, terBraak 1995). CCA is highly useful to analyse the multiple correlated variables and also helps to compare a complex relationship between species and environment (Leps & Similaur 2003) hence, it was selected for analysis to measure associations of the species with habitat and disturbance variables using Program CANOCO (CANOCO v. 4.56; terBraak 2009). In addition, the data was presented in the form of biplot (MacFaden & Capen 2002). For all analysis, a Monte-Carlo permutation test (using 499 unrestricted permutations) was used to identify the environmental variables that were significantly associated with the variation in the distribution of species (Manly 2007, Baeza *et al.* 2007, Blake & Loiselle 2018).

Table 1. Details of species, environmental and disturbance variables included in analysis

Parameters	Variables	Description and CANOCO levels
Species variables	Ungulates	Chital (CH), Northern red Muntjac (MJ), Wild boar (WB) Himalayan goral (GH)
	Carnivores	Himalayan black bear (BB), Common leopard (CLp)
	Primates	Common langur (Cla)
Habitat variables	Habitat types	Grassland (GL) *Schima-Castanopsis* forest (SCF), Sal forest (SF), Sal-Sajforest (SSF), *Alnus* Forest (AF), Sal-Saj-*Castanopsis* forest (SSCF) Mixed hardwood forest (MHF) (Pinus, Simal,Betula, Dhairo, Karam association forest)
	Forest cover	Dense forest (Den), Moderately dense (Mden), Open (Open)
	Distance to water resources (DW)	Euclidean distance measured from sampling point to the nearest waterhole
Topographic variables	Topographic structures	Structure of landscape measured in terms of slope: Plane (Pla), Moderate slope (MSlp) Sloppy area (Slp), Steep (Stp)
	Altitude (Alt)	Altitude meter above sea level measured using a Global Positioning System
Disturbance variables	Distance to roads or trails (Dist_road)	Euclidean distance measured from sampling point to the nearest trails or roads used by people
	Distance to Settlement (Dist_settl)	Euclidean distance measured from sampling point to the nearest settlements
	Habitat disturbance status	Very low (VL), Low (LW), Moderately disturb (MD), High disturb (HD), Very high disturb (VHD)

RESULTS AND DISCUSSION

Effects of habitats on distribution of mammals

Species response to different habitats of Seti River basin indicated that Himalayan goral showed a closer affinity with grass patches. Likewise, Northern red muntjacs were mostly observed in open areas, mixed hardwood forest and *Schima-Castanopsis* forest. Open grass patches inside these forest favors the presence of muntjacs. Common langurs were recorded in moderately dense area of Sal forest and Sal-Saj forest. Wild boars were recorded in moderately dense Sal forest and *Schima-Castanopsis* forest. The signs of common leopards were found in dense forest of Sal, Sal-Saj and Sal-Saj-*Castanopsis*. Very low sign of Himalayan black bear was found in dense forest area of Bandipur Rural Municipality (Fig. 2).

Similar type of study in south-eastern region of Annapurna Conservation Area of Nepal found that black bear was distributed in *Schima wallichi, Quercus* spp. forest with *Arundinaria* spp. and *Dendrocalamus* spp. (Bista & Aryal 2013). Seti River basin is human dominated where settlement areas and crop fields are intersected by forest patches. Hence, sighting of mammals and their signs were low. Previous studies in different part of the world; such as Israel (Shamoon *et al.* 2018), Malasia (Sasidhran *et al.* 2016), Indonisia (Sulistyawan *et al.* 2017) and India (Jeganathan *et al*. 2018) found similar type of results and problems in human dominated fragmented habitats (Fahrig 2003, Haddad *et al.* 2015). Northern red muntjac showed a wide range of distribution, as it is adapted to live in a wide variety of habitats including degraded and fragmented forest near human settlements (Oka 1998, Paudel & Kindlmann 2012). The preferable habitats for goral were scattered throughout the study area and they were mostly found in steep grassy slopes. A similar type of distribution pattern was reported in different works (Fakhar-i-Abbas *et al.* 2008, Hajra 2002, Mishra & Johnsingh 1996).

Effects of topography on distribution of mammals

Topography (slope of the landscape and altitude) plays a significant role on the distribution of mammals. Seti River basin possesses comparatively larger areas of sloppy, steep than moderately slope. Plane area is very low as these areas are limited to flood plains and valleys of Seti River basin. The forest of plane areas is fragmented by crop land and settlement areas. CCA analysis of the species with topographic variables showed that most of the mammals show close association with moderately slope and sloppy areas. However, Chital showed the association with plane areas as this species was only recorded in the community forest of Devghat areas (Raniban CF, Madhuban CF). Common langur was mainly recorded in slope and steep areas. Most of the signs left by Common leopard were recorded in moderately slope areas whereas the sign of Himalayan black bear was recorded in sloppy and moderately slope areas in high altitude of Seti River basin (Fig. 3).

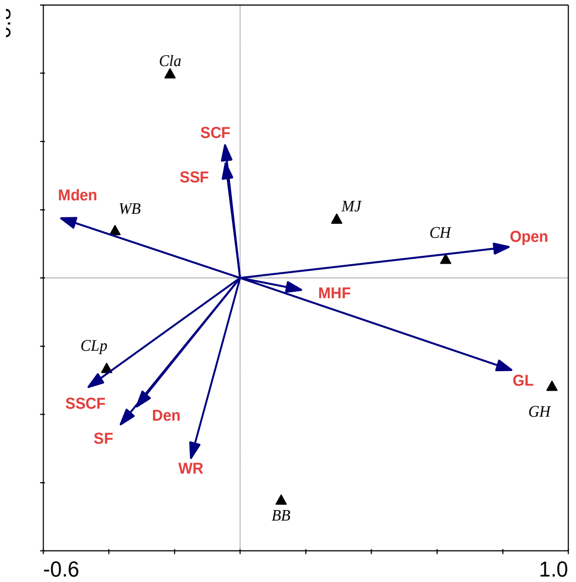

Fig. 2. CCA ordination diagram (biplot) showing species response to different habitats in SetiRiver basin. Monte-Carlo permutation test of significance of all canonical axes: Trace = 1.36, F = 2.058 P= 0.002 (with 499 permutations). First two axes are displayed. The first axis accounts for 40.2% and the second axis 22.5% of the variability (GL= Grassland, SCF= Schima-Castanopsis forest, SF= Sal forest, SSF= Sal-Saj forest, AF= AlnusForest, SSCF= Sal-Saj-Castanopsis forest,MHF= Mixed hardwood forest, Den= Dense forest, Mden= Moderately dense, open= Open, WR= Distance to water resources, CH= Chital, MJ= Northern red muntjac, GH= Himalayan goral, WB= Wild boar, BB=Himalayan black bear, CLp= Common leopard, Cla= Common langur)

Himalayan goral was closely associated with the varieties of habitats throughout the mountains (Paudel *et al.* 2015, Wegge & Oli 1997) and was reported as adapted to the steep slope (Mishra & Johnsingh 1996, Paudel & Kindlmann 2012). Himalayan black bear and Himalayan gorals are high altitude specialist mammals, therefore, mostly abundant in high altitude (Ashraf *et al.* 2016, Bista *et al.* 2018). Hence, the signs of Himalayan black bear and sighting of Himalayan goral were recorded very low in Seti River basin.

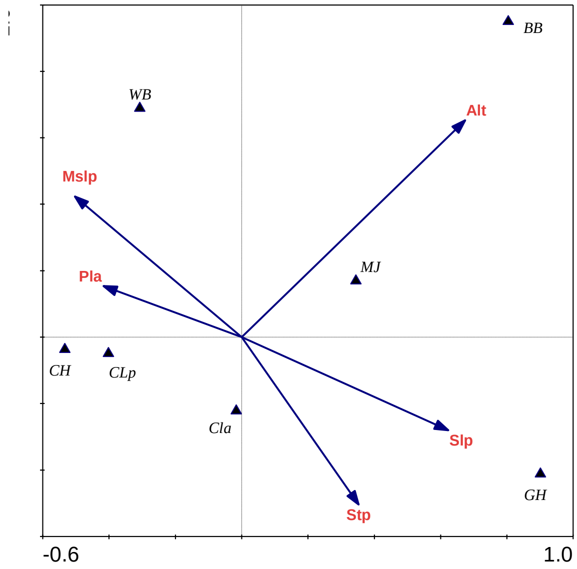

Fig. 3. CCA ordination diagram (biplot) showing species response to topography in Seti River basin. Monte-Carlo permutation test of significance of all canonical axes: Trace= 0.564, F= 1.764, P =0.01 (with 499 permutations). First two axes are displayed. The first axis accounts for 61.2% and the second axis 20.2% of the variability (Pla= Plane, MSlp= Moderate slope, Slpy= Sloppy area, Stp= Steep, Alt= Altitude, CH= Chital, MJ= Northern red muntjac, GH= Himalayan goral, WB= Wild boar, BB=Himalayan black bear, CLp= Common leopard, Cla= Common langur)

Effects of human disturbance on distribution of mammals

CCA between the mammals and HDS of study area showed very close association of chital, Himalayan gorals, Wild boar, Muntjac with low disturbed areas. Common langur showed close relation with disturbed areas, as they were recorded nearer the settlements and were very common in and around the holy place of Devghat and associated places. The signs left by the Common leopard showed close association with very low disturb areas where the abundance of Himalayan goral, Northern red Muntjac and Wild boar were more. The sign left by the Himalayan black bear was very low in this study area hence they did not show relation with disturbance (Fig. 4).

However, studies showed that Himalayan black bear mainly preferred to stay far from human disturbances (Bista & Aryal 2013). Regular disturbances caused by human activities could offer a change in distribution and behaviour of mammal that consequently increases conflict with people (Cheyne *et al.* 2016, Adhikari *et al.* 2018). Hence, the habitat and prey preference of carnivores also depends on the degree of habitat disturbances in the human dominated landscapes (Bhattarai & Kindlmann 2018). In general terms, diversity, abundance, total biomass, and mean biomass of species tend to decrease with increasing human disturbance (Oberosler *et al.* 2017). The abundance of major prey species of Common leopard and Bengal tiger except primates, was highly negatively associated with disturbances (Bhattarai & Kindlmann 2012).

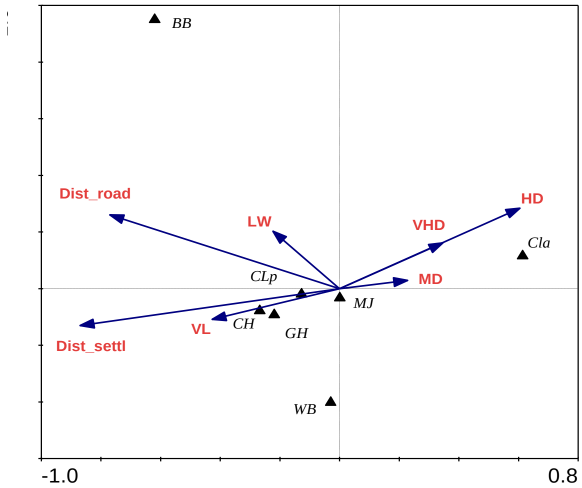

Fig. 4. CCA ordination diagram (biplot) showing species response to different habitat disturbance status (HDS) in Seti River basin. CCA ordination diagram (biplot) showing relationship abundances of the large mammals with different levels of habitat disturbance status (HDS: VHD= very high disturbance, HD= high disturbance, MD =moderately disturbance, LW= low, VL=very low, Dist_road= Distance to road or trail, Dist_settl= Distance from settlement, CH= Chital, MJ= Northern red muntjac, GH= Himalayan goral, WB= Wild boar, BB= Himalayan black bear, CLp= Common leopard, Cla= Common langur). Monte-Carlo permutation test of significance of all canonical axes: Trace= 0.912, F= 1.67, P =0.04 (with 499 permutations). First two axes are displayed. The first axis accounts for 54.9% and the second axis 22.1% of the variability

Our study found that human disturbance played significantly negative role in detection probability of target species (F= 1.67, P =0.04). Research on factors influencing the distribution of large mammals within a protected central African forest indicated that human activities significantly influence the distribution of large mammals, even within the protected areas (Blom *et al.* 2005). Human activity on trails and roads may lead to indirect habitat loss, further limiting available habitat (Rogala *et al.* 2011). Presence of wildlife from distance to roads and settlements also indicate the nature and tolerance of the wildlife towards sources of human disturbances. The CCA biplot of species with response to the distance of roads and settlements show the significant relation (F= 1.67, P =0.04) (Fig. 4). Himalayan gorals were recorded far from the roads or settlements. However, the signs of Common leopard were recorded nearer the roads or trails. It might be less disturbed due to very rare use by the people. Likewise, most of the signs of the Himalayan black bear were recorded far from the roads/trails and settlements and therefore Himalayan black bears showed less affinity with distance of roads or trails. The Northern red muntjacs were found close to the settlements as they were less sensitive to human disturbances (Mishra 1982).

CONCLUSION

The distribution of large mammals along topographic, habitat and disturbance variables varied according to the nature of species. Species response to different habitats of Seti River basin indicated that Himalayan goral showed more affinity towards steep area with grass patches but Northern red Muntjac and Common leopard showed close affinities with wide variety of habitats such as open area, mixed hardwood forest and *Schima-Castanopsis* forest and sloppy areas. Common langur was mostly recorded near the human settlements. Most of the mammals were recorded nearer to the water resources but far from the settlements and roads. The signs of presence of large mammals were recorded mostly in the habitats located in the jurisdiction of community forests. Present study clearly showed that the distributions of large mammals were greatly affected by habitat and disturbance factors. These findings may help researchers to identify the research gaps and for the natural resource managers to set the conservation strategies.

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