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# Distribution of Himalayan Red Fox (*Vulpes vulpes*), A New Neighbor to Humans in Lahaul & Spiti, Himachal Pradesh

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***Abstract***: The study aimed to assess the distribution of red fox using camera traps in Lahaul and Spiti, Himachal Pradesh. Generalized linear modelling was used to understand the influence of environmental factors governing the distribution of red fox. Total effort of 222 camera traps yielded 103 spatially independent records of Himalayan Red fox in Lahaul and Spiti. The top model insinuates that the distribution of Himalayan red fox is influenced by variables elevation and distance to village. The elevation (β= -0.0004) negatively influence the distribution of Himalayan red fox whereas distance to village (β = 0.003) indicated positive influence on the distribution of the species. Avoiding higher elevation areas and living in close vicinity with humans might be due to easy access to anthropogenic food/garbage sites without competing with other carnivores in the landscape. Playing a crucial role as a mesocarnivore, this species actively regulates prey populations, thereby contributing significantly to the maintenance of the food chain. Consequently, ensuring the stability of this species' population becomes imperative for maintaining the ecological balance.

***Keywords***: Red fox, Distribution, Camera traps, GLM, Lahaul & Spiti

The habitat use studies provide a basic understanding of species' ecology and understand their natural history, abundance, and distribution (Engler et al 2017). Understanding how the species respond to the environmental factors and how those factors are governing the distribution of species is imperative for formulating effective conservation and management plans (Singh et al 2019). The Indian Himalayan region (IHR) is home to a diverse range of flora and fauna including mesocarnivores which are distributed in the wide variety of habitats (Chandra et al 2018). Some of these species are geographically restricted and some are having a widespread distribution such as red fox (*Vulpes vulpes)*. It is distributed throughout Europe, Asia and Northern Africa, North America and Australia. In Indian Himalayan region is occupying areas from Kashmir to Sikkim (Shawl et al 2008). Being a generalist species, it is found both in natural and human-dominated landscapes in large parts of the world (Gloor et al 2001, Bidlack et al 2006, IUCN 2022). It occupies highly contrasting habitats and its distribution and abundance is determined to a large extent by food availability (Barton and Zalewski 2007, Rosalino et al 2010, Gallant et al 2012, Carricondo-Sanchez et al 2016). They play an important role in maintaining the ecosystem integrity by balancing the prey base. It preys on a wide range of animal species and feed opportunistically on food resources such as berries and human garbage (Hartova-Nentvichova et al 2010, Rosalino et al 2010). The threats to this species are highly localized and includes hunting, habitat degradation and fragmentation. However, their general versatility and eclectic diet are likely to ensure their persistence despite changes in landscape and prey base and are listed as *Least concern* according to IUCN 2022. The conservation of red fox is crucial for the survival of any top predators, as changes in preferred prey abundance could alter the population of predators and vice-versa. Literature highlights that mesocarnivore species at intermediate trophic levels generally show high species richness and diverse resource and habitat use (Prugh et al 2009, Roemer et al 2009).

In recent years mesocarnivores have received much attention due to decline of top predators (Ritchie and Johnson 2009). Several studies have indicated that the relative abundances of apex and meso-predators are negatively correlated (Berger et al 2008, Pasanen-Mortensen et al 2013). Apex predators are always dominant over and can directly influence mesocarnivores (Roemer et al 2009, De Oliveira and Pereira 2014). The manner in which terrestrial ecosystems are regulated is controversial, but it is undeniable that predators Lregulate prey populations and vice-versa and as a result maintain the ecosystem integrity. Long-term absence of such species could cause trophic cascades as prey populations would likely increase, leading to depletion of other resources. Conservation and management planning demands exhaustive information on various life history traits of species including habitat utilization pattern (Margules and Pressey 2000). Study on habitat ecology broadly pinpoints that what habitat is species preferring that may have missed by population level analysis (Habblewhite et al 2007, Schofield et al 2010). Generalized linear model is one of the powerful tool for understanding the habitat use, risk assessment and distribution of the species. In IHR few studies are available on red fox which are limited to protected areas (Ghoshal et al 2016, Reshamwala et al 2018). The Himalayan region is under tremendous pressure because of infrastructural development, climate change and other anthropogenic activities (Western et al 2009, Qasim et al 2013). These events lead to rapid habitat loss, fragmentation, and population decline of various species. Therefore study aimed to identify the factors governing the distribution of red fox using camera traps in Lahaul and Spiti, Himachal Pradesh.

## MATERIAL AND METHODS

**Study area:** The Trans-Himalayan district of Lahaul and Spiti (L&S) extends from 31°44'57" to 32°59'57"N latitudes, 76°46'29" to 78°41'34"E longitudes between the Pir Panjal Mountain chains of the Greater Himalaya and Trans Himalaya with a total area of 13,841 km$^2$ possesses forest cover of about 1.11% with varying elevation from 2327 to 6441 m (Fig. 1). The Lahaul and Spiti district hold 25% of the total cold dessert of India and is divided into Lahaul and Spiti. The Spiti region presents typical arid or xeric conditions, whereas the Lahaul valley possesses mix of great Himalayan and Trans-Himalayan condition. The Spiti region is bestowed with three protected areas, Pin Valley National Park, Kibber Wildlife Sanctuary, and Chandratal Wildlife Sanctuar, whereas the Lahaul region does not have any protected area. The land cover is mainly represented by subalpine vegetation, rolling grassland meadows, agricultural land and snow-covered permafrost area. Owing to harsh climatic conditions, low rainfall, and short growing season, the slopes of the Trans-Himalayan mountains of the landscape support low vegetation cover (<20%), and are known to harbour a unique assemblage of wild flora and fauna (Joshi et al 2006). Lahaul and Spiti only have two seasons, i.e. short-lived summers, and another is prolonged severe winter. The Lahaul valley has the sparse distribution of vegetation with dominant tree species like *Pinus wallichiana*, *Cedrus deodara*, *Abies pindrow*, *Betula utilis* and *Juniperus polycarpos* mostly at the left side of the downstream of Chandrabhaga river. The local communities largely depend on high yielding cash crops, exotic vegetables, and various fruits. Both the regions of Lahaul and Spiti provides suitable habitat for the various species such as Himalayan brown bear, Kashmir Musk deer, Siberian Ibex, Snow Leopard, Blue sheep, Himalayan red fox, Himalayan Wolf.

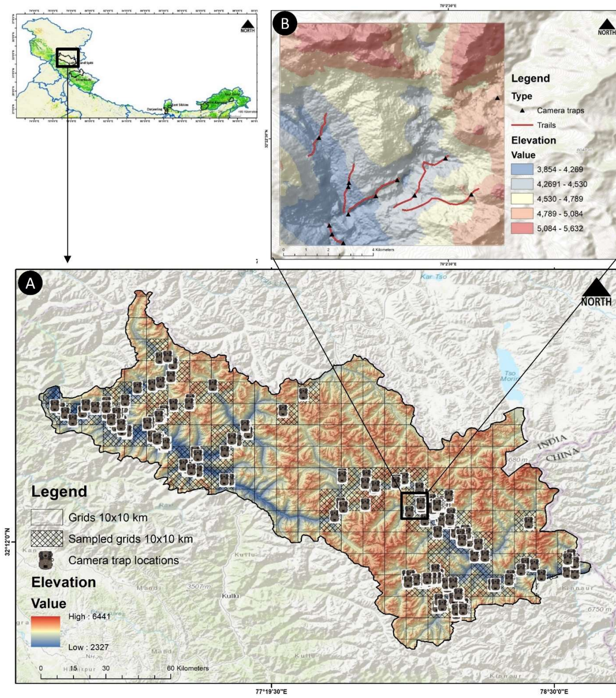


**Fig. 1.** Camera trap locations of red fox in Lahaul and Spiti, Himachal Pradesh

**Methods:** The study landscape was divided into 10 km X 10 km grids to maximize our sampling effort so that all logistically accessible grids could be covered (Sharief et al 2020). Field surveys were conducted from August 2018 to December 2020 in all the possible areas. A total of 222 camera traps were deployed covering different elevation gradients of the study landscape. The camera traps were placed at about 2.5 feet height from the ground on animal trails and paths and mostly kept 2-3 m apart from the trailsaend used ultra-compact SPYPOINT FORCE-11D trail cameras (SPYPOINT, GG Telecom, Canada, QC) during the study.

**Covariates**

A total of 20 variables were extracted either from the field or using the ArcGIS v. 10.9 software (ESRI, Redlands, CA). These covariates were classified into the following categories (topographic, habitat and anthropogenic variables). The topographic variables (elevation, slope and aspect) were generated using 30 m resolution SRTM (Shuttle Radar Topography Mission) image downloaded from Earth Explorer (https://earthexplorer.usgs.gov/). Land use landcover variables were extracted from MODIS (Moderate Resolution Imaging Spectroradiometer) Land Cover Type Product (MCD12Q1) version 6 with a 500-meter resolution to generate seventeen different land cover classes https://earthexplorer.usgs.gov/. Landscape classified into 11 different land use land cover classes which were used for further analysis. The global human footprint dataset was downloaded from the Socioeconomic Data and Applications Centre SEDAC, NASA (https://sedac.ciesin.columbia.edu). Linear features (road and water) were downloaded from DivaGis (www.diva.gis.org). All the variables were resampled with 30 arcsec ~ 1 km spatial resolution using the spatial-analyst tool in ArcGIS 10.9. Pearson correlation test was performed to identify and remove variables exhibiting significant collinearity. Variables with Pearson coefficient greater than 0.8 (rs>0.8) were dropped from further analysis (Warren et al 2010). Finally, 12 environmental variables which assumed might have ecological effect on the distribution of the species were retained for further analysis (Table 1).

**Data analysis:** Camera traps images were carefully visualized to identify the species and a capture of an animal was considered independent if the consecutive capture was at an interval of 60 minutes (Bowkett et al 2007, Marinho et al 2017). Variables which were pertinent to the ecology of the species were explicitly used for understanding the ecology of the species. Generalized linear models (GLM) were implemented in 'glmer' function of package "nlme4" in R Studio with Binomial distribution using log link function (Teixeira-Santos et al 2020). Presence/absence of the species was used as a response variable and the effect of each or a combination of the different variables on the species habitat use was predicted (Ward-Paige et al 2015). Total of 20 models were run in different combinations. To infer the results, from a set of different competing models, the best model was selected based on the Akaike's information criterion (Burnham and Anderson 2002).

**Table 1**. Variables selected after Pearson corelation (rs>0.8) on distribution of red fox in Lahaul and Spiti

| Variable | Code | Data | Source |
|---|---|---|---|
| LULC/Land use land cover type | | | |
| Western mixed coniferous forest | WMCF | MODIS MCD12Q1 16 | USGS |
| Moist Deodar forest | MDF | | |
| Dry alpine scrub | DAS | | |
| Alpine grassland | AG | | |
| Agricultural & horticultural land | AH | | |
| Distance to village | DV | Calculated using log Euclidean distance (ArcGISx) | LULC map |
| Distance to water | DW | | |
| Distance to road | DR | | |
| Topographic variables | | | |
| Aspect | ASP | SRTM | USGS |
| Slope | SLP | | |
| Digital elevation model | DEM | | |
| Anthropogenic variables | | | |
| Human footprint | HFP | SEDAC, NASA | |

## RESULTS AND DISCUSSION

Total effort of 222 camera traps yielded 103 spatially independent records of Himalayan Red fox in Lahaul and Spiti. Out of 20 models, only top two models are shown (Table 2) which explains the influence of environmental variables on distribution of Himalayan red fox. The top model based on the lowest AIC showed that the habitat use of Himalayan red fox was influenced by variables elevation and distance to village. The model assumed that habitat use of red fox varied as a function of elevation and distance to village. The results indicate that elevation ($\beta$= -0.0004) is negatively influencing the distribution of Himalayan red fox and distance to village ($\beta$ = 0.003) is positively influencing Himalayan red fox in the Lahaul and Spiti (Table 2). The generalized linear modelling was performed for Himalayan Red fox to understand the association with the habitat predictors in Lahaul and Spiti. The Red fox is one of the most widely distributed species in Lahaul and Spiti district, possibly near human settlements (Ghoshal et al 2015). The findings suggest that this species avoids high elevation areas and prefers to live near human settlements which might be due to less availability of food resources at high elevation areas and to avoid top predators such as snow leopard and wolf in the landscape. Hussain et al (2018) also suggested the ability of red foxes to exploit humans as sources of food appears to be a behavioral adaptation that helps them

**Table 2.** Top two models with beta estimates to understand the habitat association of red fox in Lahaul and Spiti District, Himachal Pradesh

| Models | Variable | Estimate with SE | Z value | Pr(>\|z\|) | K | AIC | ∆AIC |
|---|---|---|---|---|---|---|---|
| (ELE+DV) | Elevation | -0.04± 0.0001 | -2.62 | 0.008** | 2 | 252 | 0 |
| | Aspect | 0.003± 0.001 | 2.35 | 0.018* | | | |
| ELE + ASP+ DAS) | ELE | -0.001±0.0002 | -1.83 | 0.007* | 3 | 254.47 | 0.47 |
| | ASP | 0.007±0.001 | 2.01 | 0.0006 | | | |
| | DAS | 0.002±0.0005 | -3.62 | 0.00002 | | | |

ELE- elevation, DV -Distance to village, ASP- aspect, DAS- dry alpine scrub to survive in the arid Trans Himalayan landscape. During survey period frequently observed red fox near human settlements which may be due to food availability from garbage sites, prey species available at lower elevations and to avoid resource competition. Cagnacci et al (2004) also observed that species avoid higher elevation during the winter season due to availability of prey species at the lower elevation. Increased food availability at garbage sites and absence of large carnivores increased the population of red fox in Scandinavia (Selas and Vik 2006). The rapid increase in tourism has led to a drastic increase in the number of restaurants and hotels in the trans Himalayan landscape of Lahaul and Spiti that have considerably contributed to garbage generation (USL 2011). Ghoshal et al (2015) suggested the positive association of red fox occurrence with the garbage sites which is a source of food for red fox. Increased food availability at garbage sites and absence of large carnivores increased the population of red fox in Scandinavia (Selas and Vik 2006, Elmhagen and Rushton 2007).

## CONCLUSION

Being a mesocarnivore species red fox plays a crucial role in regulating prey populations and shaping the plant community structure by its deed dispersal ability, thereby contributing significantly to the maintenance of the food chain. Therefore considering the importance of this species it is vital to understand the influence of environmental predictors on its distribution for effective management and planning. The garbage sites are not only the source of food for red fox but also facilitate free ranging dogs which later on becomes feral and predate on red foxes. Hence management of red fox populations in high altitudes should take into account the availability of garbage sites and increasing population of stray dogs.

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## AUTHORS CONTRIBUTION

A Sharief, LK Sharma, BD Joshi conceived the idea. V Kumar, R Dutta, H Singh, S Bhatacharya, AP Singh conducted field survey to collect data on Red fox. A Sharief performed the geospatial analysis and wrote the manuscript. LK Sharma, BD Joshi, M Thakur edited the manuscript. LK Sharma provided the logistic support.

## REFERENCES

Bartoń KA and Zalewski A 2007. Winter severity limits red fox populations in Eurasia. *Global Ecology and Biogeography* **16**(3): 281-289.

Berger KM, Ges EM and Berger J 2008. Indirect effects and traditional trophic cascades: a test involving wolves, coyotes, and pronghorn. *Ecology* **89**(3): 818-828.

Bidlack AL, Merenlender A and Getz WM 2008. Distribution of nonnative red foxes in East Bay oak woodlands. *US For Serv Gen Tech Rep PSW* **217**: 541-548.

Bowkett AE, Rovero F and Marshall AR 2008. The use of camera-trap data to model habitat use by antelope species in the Udzungwa Mountain forests, Tanzania. *African journal of ecology* **46**(4): 479-487.

Breslow NE and Clayton DG 1993. Approximate inference in generalized linear mixed models. *Journal of the American statistical Association* **88**(421): 9-25.

Burnham KP and Anderson DR 2002. Model selection and multimodel inference: A practical information–theoretic approach, (2nd edn) – Springer Science.

Cagnacci F, Meriggi A and Lovari S 2004. Habitat selection by the red fox *Vulpes vulpes* (L. 1758) in an Alpine area. *Ethology Ecology & Evolution* **16**(2): 103-116.

Carricondo-Sanchez D, Samelius G, Odden M and Willebrand T 2016. Spatial and temporal variation in the distribution and abundance of red foxes in the tundra and taiga of northern Sweden. *European Journal of Wildlife Research* **62**(2): 211-218.

Chandra K, Joshi BD, Singh A, Bharadwaj M, Thakur M and Sharma LK 2020. Current status and distribution of Threatened Vertebrates in Indian Himalayan Region: Focus on conservation and Management Planning. *Zoological Survey of India.* 276

De Oliveira T and Pereira JA 2014. Intraguild predation and interspecific killing as structuring forces of carnivoran communities in South America. *Journal of Mammalian Evolution* **21**(4): 427-436.

Elmhagen B and Rushton SP 2007. Trophic control of mesopredators in terrestrial ecosystems: top-down or bottom--up? *Ecology letters* **10**(3): 197-206.

Engler JO, Stiels D, Schidelko K, Strubbe D, Quillfeldt P and Brambilla M 2017. Avian SDMs: current state, challenges, and opportunities. *Journal of Avian Biology* **48**(12): 1483-1504.

Gallant D, Slough BG, Reid DG and Berteaux D 2012. Arctic fox versus red fox in the warming Arctic: four decades of den surveys in north Yukon. *Polar biology* **35**(9): 1421-1431.

Ghoshal A, Bhatnagar YV, Mishra C and Suryawanshi K 2016. Response of the red fox to expansion of human habitation in the Trans-Himalayan mountains. *European Journal of Wildlife Research* **62**(1): 131-136.

Gloor S 2002. *The rise of urban foxes (Vulpes vulpes) in Switzerland and ecological and parasitological aspects of a fox population in the recently colonised city of Zurich* (Doctoral dissertation, Universität Zürich). 1-118.

Hartová-Nentvichová M, Šálek M, Červený J and Koubek P 2010. Variation in the diet of the red fox (*Vulpes vulpes*) in mountain habitats: effects of altitude and season. *Mammalian biology* **75**(4): 334-340.

Hebblewhite M and Haydon DT 2010. Distinguishing technology from biology: a critical review of the use of GPS telemetry data in ecology. *Philosophical Transactions of the Royal Society B: Biological Sciences* **365**(1550): 2303-2312.

IUCN. 2022. *Vulpes*. The IUCN Red List of Threatened Species. Version 2022-2. https://www.iucnredlist.org. ISSN 2307-8235. Accessed on 04 Dec 2022.

Joshi PK, Rawat GS, Padilya H and Roy PS 2006. Biodiversity characterization in Nubra Valley, Ladakh with special reference to plant resource conservation and bioprospecting. *Biodiversity & Conservation* **15**(13): 4253-4270.

Marinho PH, Bezerra D, Antongiovanni M, Fonseca CR and Venticinque EM 2018. Activity patterns of the threatened northern tiger cat *Leopardus tigrinus* and its potential prey in a Brazilian dry tropical forest. *Mammalian Biology* **89**: 30-36.

Margules CR and Pressey RL 2000. Systematic planning for biodiversity conservation. *Nature* **405**: 243-253.

Pasanen-Mortensen M, Pyykönen M and Elmhagen B 2013. Where lynx prevail, foxes will fail–limitation of a mesopredator in Eurasia. *Global Ecology and Biogeography* **22**(7): 868-877.

Prugh LR, Stoner CJ, Epps CW, Bean WT, Ripple WJ, Laliberte AS and Brashares JS 2009. The rise of the mesopredator. *Bioscience* **59**: 779-791.

Qasim M, Hubacek K, Termansen M and Fleskens L 2013. Modelling land use change across elevation gradients in district Swat, Pakistan. *Regional environmental change* **13**(3): 567-581.

Ritchie EG and Johnson CN 2009. Predator interactions, mesopredator release and biodiversity conservation. *Ecology Letters* **12**(9): 982-998.

Rosalino LM, Sousa M, Pedroso NM, Basto M, Rosario J, Santos MJ and Loureiro F 2010. The influence of food resources on red fox local distribution in a mountain area of the western mediterranean. *Vie et Milieu/Life & Environment* 39-45.

Roemer GW, Gompper ME and Van Valkenburgh B 2009. The ecological role of the mammalian mesocarnivore. *BioScience* **59**(2): 165-173.

Reshamwala HS, Mahar N, Dirzo R and Habib, B 2018. Risky home with easy food: Denning of a generalistic and widely distributed carnivore red fox. *BioRxiv*, 411686.

Schofield G, Lilley MK, Bishop CM, Brown P, Katselidis KA, Dimopoulos P and Hays GC 2009. Conservation hotspots: implications of intense spatial area use by breeding male and female loggerheads at the Mediterranean's largest rookery. *Endangered Species Research* **10**: 191-202.

Selås V and Vik JO 2006. Possible impact of snow depth and ungulate carcasses on red fox (Vulpes vulpes) populations in Norway, 1897–1976. *Journal of Zoology* **269**(3): 299-308.

Sharief A, Joshi BD, Kumar V, Kumar M, Dutta R, Sharma CM and Chandra K 2020. Identifying Himalayan brown bear (Ursus arctos isabellinus) conservation areas in Lahaul Valley, Himachal Pradesh. *Global Ecology and Conservation* **21:** e00900.

Shawl T, Tashi P and Panchaksharam Y 2008. *Field Guide Mammals of Ladakh*. WWF-India 1-108.

Singh PB, Saud P, Cram, D, Mainali K, Thapa A, Chhetri NB and Jiang Z 2019. Ecological correlates of Himalayan musk deer *Moschus leucogaster*. *Ecology and Evolution* **9**(1): 4-18.

Teixeira DF, Guillera-Arroita G, Hilário RR, Fonseca C and Rosalino L 2020. Influence of life-history traits on the occurrence of carnivores within exotic Eucalyptus plantations. *Diversity and Distributions* **26**(9): 1071-1082.

Warren DL, Glor RE and Turelli M 2010. ENMTools: a toolbox for comparative studies of environmental niche models. *Ecography* **33**(3): 607-611.

Ward-Paige CA, Britten GL, Bethea DM and Carlson JK 2015. Characterizing and predicting essential habitat features for juvenile coastal sharks. *Marine Ecology* **36**(3): 419-431.

USL 2011. *Management plan for upper Spiti landscape including the Kibber wildlife sanctuary.* Wildlife wing Himachal Pradesh Forest Department, Shimla and Nature Conservation Foundation, Mysore. 1-291.

Western D, Russell S and Cuthill I 2009. The status of wildlife in protected areas compared to non-protected areas of Kenya. *PloS one* **4**(7): e6140.

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