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Habitat Suitability Modeling of Asiatic Black Bear (*Ursus thibetanus*) in Azad Jammu and Kashmir, Pakistan

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UA and BA designed the study. UA, RAM, LAK and MBK carried out field work and data analysis. UA drafted the article. MK carried out Maxent analyses. MSA, RAM and BA reviewed and improved the manuscript.

Key words
***Ursus thibetanus*, Species Distribution model, Himalaya range, Maxent, Conservation planning**

ABSTRACT

Effective conservation and management of Asiatic black bear *Ursus thibetanus* requires the identification and in-depth knowledge of suitable habitats. Habitat suitability models (HSMs) have wide use in the understanding of niche requirements, hence prioritizing management and conservation issues for threatened species. This study aimed to identify the current range and suitable habitat of black bear in Azad Jammu and Kashmir (AJ&K) using the maximum entropy model. Field surveys were conducted between 2015 and 2020 to collect data using direct and indirect evidence. Maximum entropy (Maxent) models revealed an average AUC of 0.84 ($\pm$0.03) designating a high accuracy. Main predictors of HSM of black bear were elevation (34%), temperature (23%) and land cover (16%). This model predicted 1703 km^2 as suitable habitat for black bear in Azad Jammu and Kashmir while 5802 km^2 was not suitable for the species distribution. Most of the suitable habitat of Asiatic black bear was confined to the Line of Control (LoC). A park for peace is suggested alongside the LoC to promote the endurance of black bear and other wildlife species. Low numbers of black bear are found in the extreme north of Neelum valley, Lachrat, and Bagh study sites where habitat degradation is considerable. Habitat management practices including preventing illegal extraction of medicinal herbs and lumbering, lessen overgrazing pressure and support reforestation are required to be applied in these areas. These conservation measures will turn unsuitable habitats into suitable ones and also provide connecting corridors for black bear of Neelum particularly to the extended habitats of Gilgit Baltistan and Mansehra regions of Pakistan.

INTRODUCTION

Black bear, *Ursus thibetanus,* is considered the species of interest to a plethora of people, such as hunters, wildlife managers, local herders, owing to their variation in diet adaptability to different habitats, which frequently leads to wildlife-human conflicts (Bashir *et al.*, 2018). They inhabit subtropical to temperate regions that are characterized by highly variable climatic conditions and resource availability in space and time (Bashir *et al.*, 2018; Bista *et al.*, 2018; Farashi and Erfani, 2018). Moreover, despite black bear having great adaptability to varying habitat conditions and biological resources (Escobar *et al.*, 2015; Bashir *et al.*, 2018), most of their natural habitats are being degraded under human pressure in the Himalayan region (Bista *et al.*, 2018; Farashi and Erfani, 2018). Asiatic black bear potential habitats have been extensively exploited, particularly extension in human settlements at the expense of wild territory. Human population coupled with road networks, habitat simplification, and degradation, pollution, exploitation of natural resources, and conflict with black bear (Takahata *et al.*, 2013).

Distribution and space use of black bear has been studied across their geographic range and a great deal of variations exists in the selection and avoidance of habitats (Izumiyama and Shiraishi, 2004; Trent, 2010). Asiatic black bear is distributed in 18 countries of Southern and Eastern Asia. It is categorized as vulnerable by IUCN

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Red Data Book (Sathyakumar and Choudhury, 2007; Garshelis and Steinmetz, 2016; Bashir *et al*., 2018) at golabl scale, however, its country status is endangered in Pakistan (Sheikh and Molur, 2004). Black bear faced a severe eradication from much of their distribution range in Pakistan. Habitat requirements of black bear need a prime focus as their conservation remains challenged due to conflict with humans and larger home ranges distressed due to change in land-use patterns. Literature review revealed that suitable habitats of black bear are located in mountainous areas having substantial understory vegetation, an abundance of food, relatively difficult terrain, and adequate denning sites. Bear prefers steep southern slopes in the vicinity of rivers and trails (Reid *et al*., 1991; Takahata *et al*., 2013; Bashir *et al*., 2018) and avoids rocky and un-vegetated areas and high human density (Bista *et al*., 2018).

Effective conservation and management of Asiatic black bear requires identification and indepth knowledge of lasting suitable habitats and establishment of boundaries at an ecological meaningful scale (Fleishman *et al*., 2000; Edwards *et al*., 2008; Doko *et al*., 2011). Habitat constraints, degradation, anthropogenic factors, and species distribution play a critical role in the conservation of this species. Black bear due to its conflict with humans, large home and low population size are particularly sensitive to habitat fragmentation and degradation (Morovati *et al*., 2020). Even though black bear is widely studied, lack of information on habitat suitability could hinder the conservation efforts in South Asia (Bashir *et al*., 2018; Deb *et al*., 2019; Morovati *et al*., 2020).

Habitat modeling gives a dynamic and suitable method to describe geographic range, guide research, and establish substantial opportunities for the conservation of a species (Bashir *et al*., 2018). Wildlife managers rely on the models that predict the suitability of wild species habitats, especially the large carnivores. The species distribution model (SDM) involved a set of techniques, biogeographical understandings, ecological interactions, and the relationship between animals and their physical environment (Hirzel *et al*., 2002; Deb *et al*., 2019; Morovati *et al*., 2020). These models, based on the presence-only data, explain the ecological needs of a species, distribution extant and infer the present and future of a species. SDMs are coming into the limelight of ecologists due to their wide use in the understanding of niche requirements, prioritizing management and conservation issues of threatened species (Escobar *et al*., 2015), and predicting climate change impacts (Hirzel *et al*., 2006; Zahoor *et al*., 2021). Conflict management becomes easier and productive when SDMs are used. This low-cost and convenient modeling is widely used to assess habitat suitability (Almasieh *et al*., 2016), provides a reliable map of large mammals' habitats and the environmental variables having well-known effects on their ecology. SDM has a low error rate though models become more complicated in natural landscapes having diverse spatial variations in their ecological environment (Duflot *et al*., 2018). They could model habitat at good on presence-only data even, particularly with small number of occurrence points (Cabral and Kreft, 2012; Hastie and Fithian, 2013; Sheehan *et al*., 2017; Wahid *et al*., 2017; Tang *et al*., 2018).

SDM helps managers to develop an effective conservation plan in a short period. Habitat modeling predicts the potential distribution of species, evaluates impacts of various ecological factors, anthropogenic impressions and biological risk factors. Conservation of black bear in terms of habitat management can be applied based on the identification of potential habitats. Lack of data on habitat suitability in AJ&K hinders conservation efforts, particularly for large carnivores. However; a recent trend in habitat SDM has been noted in AJ&K including climate-based modeling on the Asiatic black bear (Escobar *et al*., 2015; Kabir *et al*., 2017; Zahoor *et al*., 2021). Escobar *et al*. (2015) and Kabir *et al*. (2017) discussed habitat use of wolf (*Canis lupus*) and Asiatic black bear respectively, however, Escobar *et al*. (2015) and Zahoor *et al*. (2021) covered a small portion of the Asiatic black bear distribution range in AJ&K. To fulfill this knowledge gap, present study aimed to, (i) investigate the distribution extent of Asiatic black bear in AJ&K, (ii) Identify the impact of environmental and anthropogenic variables on the distribution range of black bear, (iii) recognize the suitable habitat of Asiatic black bear in the distribution range in AJ&K.

MATERIALS AND METHODS

Study area

The study area consisted of the five northern districts of AJ&K located at 73.30° to 75.0° E and 33.10° to 35.10° N, covering an area of 8710 km^2 at an elevation range of 564 m to 6326 m (Fig. 1A). This area is bordered by Gilgit Baltistan (GB) in the north, Punjab province in the south, Indian occupied Kashmir in the east, and Khyber Pakhtunkhwa (KP) in the west. Cumulatively this area has a population of 1.59 millin people. The average population density was recorded at 213 individuals/km^2. This area consists of 56.3% of the total area of the state of AJ&K populating 39.5% of the total state inhabitants. Most of the population is found in small villages, towns, and settlements scattered in valleys, terraces, and mountains. Their settlement is based on the availability of water and agricultural land, thus population density varied accordingly (GoAJ&K, 2019). This area falls under western Himalayas having rich in biodiversity as compared to southern parts of the State. The study area was divided into 17 study localities based on their topography and natural barrier to black bear traversing (Fig. 1B). A great deal in elevation gradient (564 to 6326 m) provides a wide range of habitats such as moist warm temperate (Haveli) to cold dry temperate (Neelum valley, Machiara National Park), subalpine and alpine (uppermost reaches in Neelum valley and Leepa). Neelum valley's northern portion such as Ghamot National Park and Shounthar valley consists of rocky steep slopes and glacial moraine. This variation in ecological zones supports a variety of common and threatened life including *Catreus wallichii*, *Anthropoides virgo*, *Tragopan melanocephalus*, *Canis lupus*, *Panthera pardus*, *Panthera uncia*, *Eupetaurus cinereus*, *Ursus thibetanus*, *Ursus arctos*, *Martes foina*, *Ovis vignei,* and *Moschus cupreus* (Ali *et al*., 2007, 2016; Qamar *et al*., 2012).

Quercus incana, *Quercus dilatata*, *Salix denticulata*, *Viburnum grandiflorum*, *Corylus colurna*, *Zizyphus nummularia*, *Pinus wallichiana*, *Cedrus deodara*, *Pinus roxburghii*, *Arisaema jacquemontii*, *Aconitum heterophyllum*, *Aesculus indica*, *Rubus fruticosus*, *Artemisia vulgaris* and *Bistorta amplexicaulis* are important floral species (Shaheen *et al*., 2012, 2016; Dar *et al*., 2014; Khan *et al*., 2019).

The mean annual rainfall ranges from 1000 mm to 2000 mm, 30-60% of this precipitation is in the form of snow in northern districts. The snowline in winter is 1200 m, while in summer it rises to 3300 m (Akbar, 2016). The minimum and maximum temperatures are -6 °C and 45°C, respectively (Ashraf *et al*., 2012), with significant variations between different regions (Akbar, 2016). The average maximum temperature ranges from 20°C to 32°C while the average minimum temperature range is 4 to 7°C. This region is influenced by monsoon systems (water vapor-laden winds from the Indian Ocean) and westerly winds that come from the Caspian and Mediterranean Sea (Ashraf *et al*., 2012).

Data collection

Seasonal filed surveys were conducted to record data on the presence of Asiatic black bear during 2015-2020. Line transect method was used to record Asiatic black bear direct and indirect evidence. Randomly laid transects (n=129) of variable length (0.5 to 7.5 km) were parallelly walked by 3-7 expert team members and evidence like footprints, scats, dens, ground digging, and claw marks or debarking of trees were recorded. Crop raiding and livestock depredation events were reorded with the assistance of local people. No other bear species was found sympatric in the study area, therefore scats, footprints, crop raiding pattern, livestock killing and claw marks were easily identified. Garmin eTrax (30x) GPS devices were used to record coordinates of bear sign and length of transects. ArcGIS (ver. 10.4) and Maxent (ver. 3.3.4) were used to process data and develop habitat modeling.

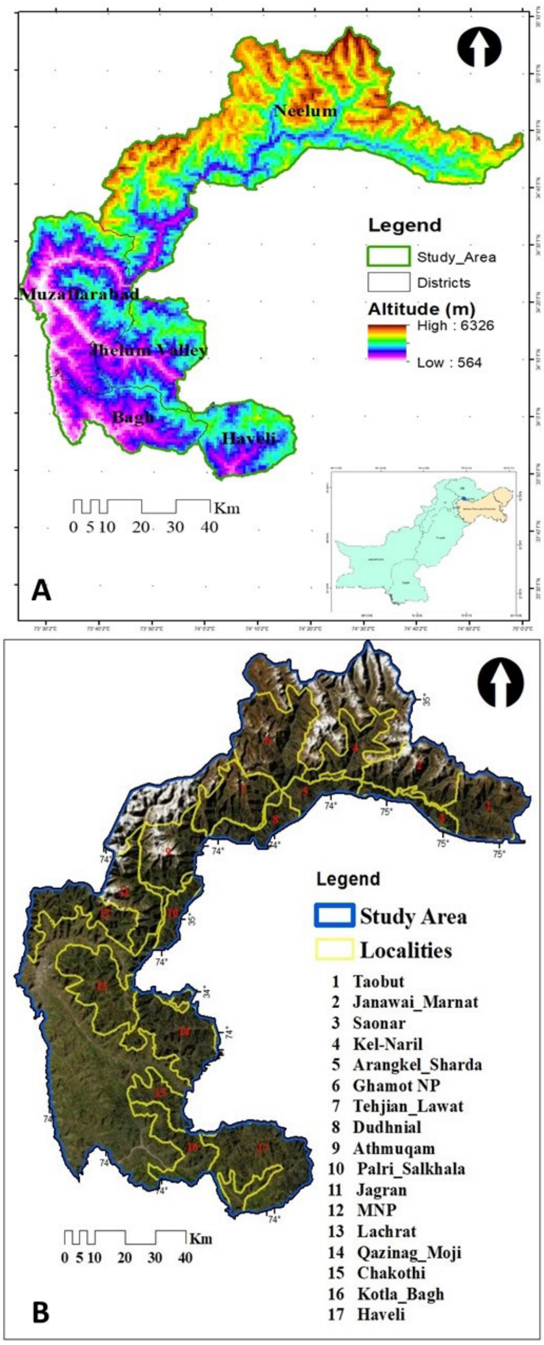

Fig. 1. Map of the study area showing northern districts (A), and different study sites (B) in AJ&K.

Model preparation and environmental variables

Presence records obtained during field surveys were processed in ArcGIS (ver. 10.4) for spatial autocorrelation using average nearest neighbor analyses to eliminate spatially correlated data points and assure independence (Escobar *et al*., 2015; Kabir *et al*., 2017; Zahoor *et al*., 2021). This analysis reduced the initial data point to 51 independent locations which were used to generate present SDMs for Asiatic black bear. A combination of environmental, topographic and anthropogenic variables was used for modeling the suitable habitat of Asiatic black bear. Variables selection was based on expert opinion and existing literature on the species (Escobar *et al*., 2015; Almasieh *et al*., 2016; Wahid *et al*., 2017; Bashir *et al*., 2018; Bista *et al*., 2018; Morovati *et al*., 2020) and study area (Kabir *et al*., 2017). A range of environmental variables that influence the distribution of black bear were used in analysis including 19 bioclimatic variables, slopes, land cover, soil type, distance to human settlements, distance to river, distance to roads, normalized difference vegetation index (NDVI) and vector ruggedness measures (Table I) (Bashir *et al*., 2018). Land cover was obtained from the Global Land Cover 2000 database (https://lta.cr.usgs.gov/glcc/globdoc2_0). Altitude and bioclimatic variables were obtained from the WorldClim database (https://www.worldclim.org/data/bioclim.html). Euclidean distance tool in ArcGIS was used to calculate the distance to rivers, distance to settlements and distance to roads. Soil, vector ruggedness measures (SRTM 90m DEM) and NDVI were obtained from NASA's website (http://modis- land.gsfc.nasa.gov/vi.html).

Table I. Environmental variables used to develop habitat suitability models of ABB in AJ&K.

Environmental variables	Codes	Data Source
Annual mean temperature	Bio_1	www.worldclim.org/current
Mean diurnal range (mean of monthly (max temp - min temp)	Bio_2	
Isothermality (BIO2/BIO7) (×100)	Bio_3	
Temperature seasonality (standard deviation ×100)	Bio_4	
Max temperature of warmest month	Bio_5	
Min temperature of coldest month	Bio_6	
Temperature annual range (BIO5-BIO6)	Bio_7	
Mean temperature of wettest quarter	Bio_8	
Mean temperature of driest quarter	Bio_9	
Mean temperature of warmest quarter	Bio_10	
Mean temperature of coldest quarter	Bio_11	
Annual precipitation	Bio_12	
Precipitation of wettest month	Bio_13	
Precipitation of driest month	Bio_14	
Precipitation seasonality (Coefficient of Variation)	Bio_15	
Precipitation of wettest quarter	Bio_16	
Precipitation of driest quarter	Bio_17	
Precipitation of warmest quarter	Bio_18	
Precipitation of coldest quarter	Bio_19	
Euclidean distance to human settlement (m)	Set_distt	Calculated by using Euclidean distance tool in ArcGIS 10.4
Euclidean distance to road (m)	Road_distt	
Euclidean distance to rivers (m)	River_distt	
Digital soil map of the world	Soil	FAO, 2003, digital soil map of the world
Slope of the area	Slope	derived from alt in Arc GIS 10.4
Elevation above sea level (m)	Alt	SRTM/www.worldclim.org/current
Normalized difference vegetation index	NDVI (MODIS)	http://modis-land.gsfc.nasa.gov/vi.html
Global land cover 2000 glc2000	Glc2000	https://lta.cr.usgs.gov/glcc/globdoc2_0 38
Vector ruggedness measure	vrmint	SRTM 90m DEM by Center for Nature and Society, Peking University

Before generating models, a Pearson's correlation was calculated and highly correlated variables (>0.70) were removed. Passing through this screening, 13 environmental variables were selected based on their applicability to the scale of the study area, their biological importance, and relevant predictive power. All the variables were prepared conforming cell size (30-arc second resolution (0.93 × 0.93 km = 0.86 km^2 at the equator)), geographic extent, projection, and ASCII using the resample, clip, mask, and conversion tools in ArcGIS. Variables were used for model training including distance to rivers (m), distance to roads (m), mean diurnal range (°C), mean temperature of the wettest quarter (°C), annual precipitation (mm), altitude (m), soil and global land cover.

Maxent model

The Maxent (maximum entropy) algorithm produces good results even with low sample sizes and is comparatively useful to operate without data on true absence (Su *et al*., 2018; Deb *et al*., 2019). Based on better performance at a relatively small number of data points, presence-only records of Asiatic black bear were used in habitat modeling in Maxent. Following setting was applied in setting options: auto features; random seed; write plot data; remove duplicate presence records; give visual warming; show tooltips; regularization multiplier (fixed at 1). Models were run with 10 replicates effect 10,000 maximum number of background points, 1000 maximum iterations, convergence threshold of 0.00001 with cross-validation run type following (Bashir *et al*., 2018; Kabir *et al*., 2017; Waseem *et al*., 2020) recommended for small sample size analysis, this run type allows to replicate n sample sets eliminating a location at each step (Kabir *et al*., 2017; Waseem *et al*., 2020; Zahoor *et al*., 2021). Such settings are conservative enough to allow the algorithm to get close to convergence and enhance performance (Wahid *et al*., 2017).

Model-based final logistic output gave suitability values from 0 (not suitable habitat) to 1 (suitable habitat). The 10th percentile was taken as the threshold value for describing the species' presence following (Escobar *et al*., 2015; Kabir *et al*., 2017; Bashir *et al*., 2018). The threshold value was used to redefine this model into a binary presence/absence map. Jackknife sensitivity analysis was used to evaluate the accurate effect of each variable in the geographic distribution model. Response curves derived from univariate models were plotted to examine how each environmental variable influenced presence probability (Kabir *et al*., 2017; Deb *et al*., 2019). Model validation was tested using the area under ROC curve (AUC) (Doko *et al*., 2011; Wahid *et al*., 2017). AUC values below 0.70 are suitable, 0.7 to 0.9 good, and above 0.9 denotes excellent model performance (Morovati *et al*., 2020).

RESULTS

Data revelaed that the Asiatic black bear is currently confined to the northern districts of AJ&K i.e. Haveli, Bagh, Jhelum Valley, Muzaffarabad and Neelum. Direct and indirect evidences of black bear were recorded in all 17 study localies, however, frequently found in localities Saonar, Sharda, Dudhnial, MNP and Qazinag. Black bear distribution was abundant in mixed forests, low human population areas and near the Line of Control (2).

Habitat suitability model

Present habitat suitability model successfully depicted the potential habitat of the Asiatic black bear that varied spatially reflecting wide-spread presence at medium altitude and along the Line of Control (Fig. 2). The binary map suggested that suitable habitat comprised 20% of the total distribution area of Asiatic black bear (Fig. 3). Model tested omission and predicted area as a function of the cumulative threshold (Fig. 4). Maxent model revealed an average AUC of 0.84 ± 0.03 (on a scale of 0-1, where 1 designates for perfect decimation of presence points from pseudo-absence points) indicating the high accuracy of this model (Fig. 5). Bear distributed in all study localities however the topographic position was an important predictor variable; altitude had the maximum probability of the presence of Asiatic black bear. Land cover plays a vital role in the distribution and abundance of black bear (Table II). Most of the study area is covered by broadleaved and conifer forests and shrubland. Habitat suitability models suggested the highest probability of the presence of black bear in the mixed deciduous forest followed by dry temperate forest, and alpine scrub while alpine grasslands were associated with a low probability of bear distribution. This model predicted 1703 km^2 as suitable habitat for black bear in AJ&K while 5802 km^2 was less suitable for species distribution (Fig. 6).

The jackknife-cross-validation test produced the relative contribution and permutation of each environmental variable using Maxent. The species distribution model for black bear in AJ&K revealed that the main predictors for habitat suitability was DEM, temperature, land cover, and precipitation (Table II). Distance to the road, river, soil type, and human settlement contributed relatively little impact on SDM.

The classification of the habitat suitability based on Maxent analysis and a suitable habitat indicated the area in which the black bear population can prosper effectively based on the covariates used in the analysis. Less suitable habitat indicated the low density of Asiatic black bear presence signs and thus have a low probability of population survivability. Likewise, unsuitable habitat is the area with a low chance of black bear existence.

Table II. Relative contribution of the environmental variables to the species distribution model (SDMs) for ABB.

Environmental variables	Acronym	Percent contribution	Permutation importance
Elevation	Alt	34.8	51.6
Mean temperature of coldest quarter	bio11	23.4	23
Global land cover	glc2000	16.2	3
Mean precipitation of driest quarter	bio17	11.8	1.6
Slope	slope	2.9	6.9
Precipitation of wettest quarter	bio16	2.9	1.2
Mean diurnal range (Mean of monthly (max temp- min temp)	bio2	2.7	3
Normalized difference vegetation index	ndvi	2.1	3.7
Vector ruggedness measure	vrmint	1.5	2.7
Digital soil map of the world	soil	0.6	0.1
Euclidean distance to road (m)	Road_distt	0.5	2.6
Euclidean distance to settlement (m)	Set_distt	0.5	0.2
Euclidean distance to rivers (m)	River_distt	0.1	0.4

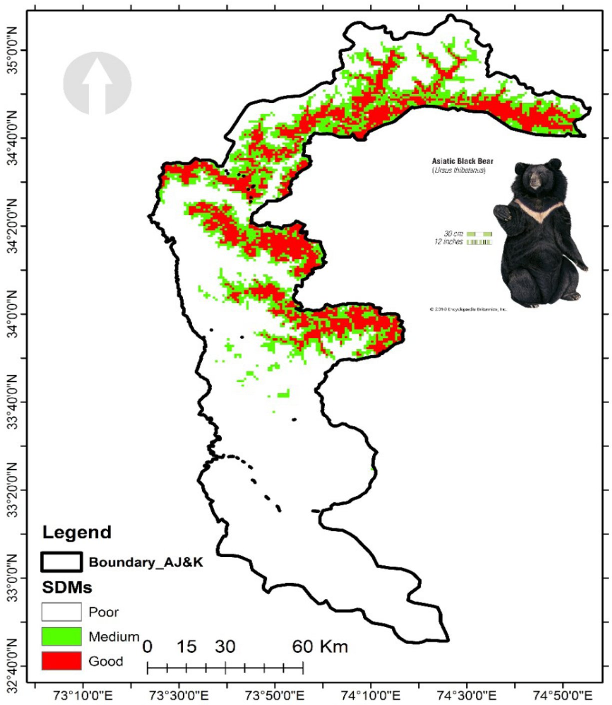

Fig. 2. SDMs prediction of Asiatic black bear distribution in AJ&K.

Spatial distribution of black bear confined to water resources, highly vegetated patches, and at a specific altitude. Response curves indicated variation in the logistic prediction as environmental variables changed whereas all other variables persisted at their average sample values. Altitude significantly affects the probability of black bear presence, reaching a maximum of 2500 m altitude. Bear presence decreased below 2000 and above 3000 m elevation (Fig. 6).

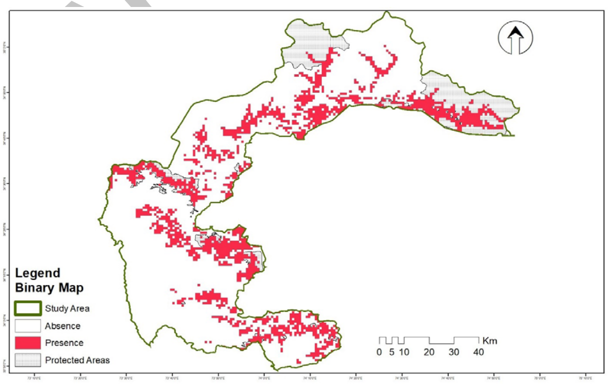

Fig. 3. Binary map of Asiatic black bear presence/absence in the study area.

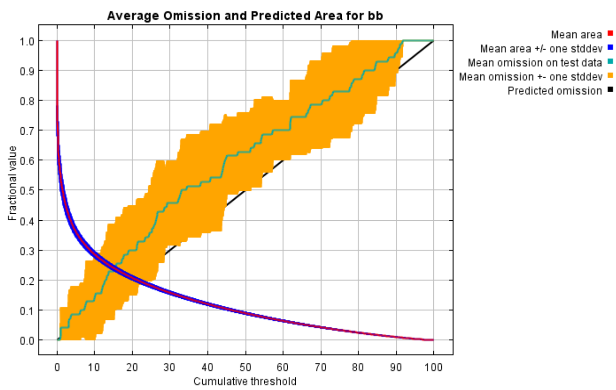

Fig. 4. Averaged omission and predicted area for Asiatic black bear presence illustrated the test omission rate and predicted area as a function of the cumulative threshold, averaged over the replicate runs.

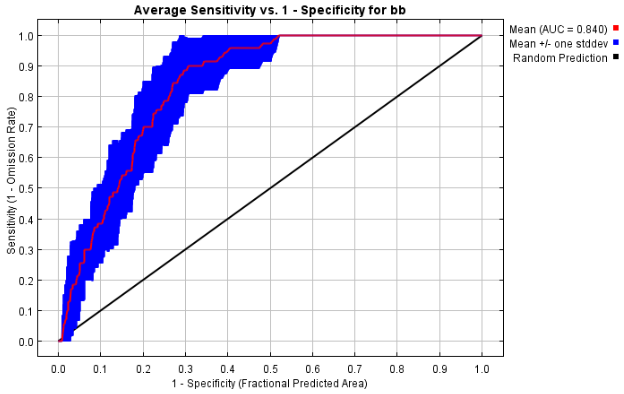

Fig. 5. Analysis of omission/commission showing how well the model accurately predicted ABB presence; the AUC of 0.840 means that the model is an excellent predictor of ABB presence as Maxent output.

The mean temperature of the coldest quarter ranged from -10˚C to 10˚C with the highest value (0.65) probability of presence around 0˚C. Global land cover ranged from 0 to 24. Bear presence rapidly increased at 2 reaching maximum values (0.64) at 3 and then it started a gradual decrease towards higher numbers.

DISCUSSION

Black bear is distributed in the northern part of AJ&K. Black bear distribution showed a variety of habitats in the study area. These are alpine scrub (at Kel and Taobut locality), watercourses (Lawat and Dudhnial localities), high-temperature zone (Haveli), and colder region (MDNP). Black bear is noted in alpine zones occasionally and their preferred altitude ranged between 2000 to 3000 m. Bashir *et al*. (2018) also reported rather rare visits of this species in alpine meadows and maximum altitude was recorded as 4250 m.

The Maxent model provided a reliable predictive map of black bear habitat and the environmental predictor effects fitted well with the known ecology of the species. Present model predicted the bear distribution impacted by elevation, forest cover and temperature with a mean AUC value of 0.84 ± 0.036, which was better than Deb *et al*. (2019) (0.8±0.05) in South Asia. Elevation played a critical role in defining the habitat suitability of black bear apparently by governing precipitation and temperature that in turn control plant growth (Hwang *et al*., 2010; Bashir *et al*., 2018). Asiatic black bear habitat selection patterns at a small scale seem to be influenced by a complex interaction among habitat attributes, environmental variables, and human disturbance. Takahata *et al*. (2013) reported the association of Asiatic black bear with high altitudes,

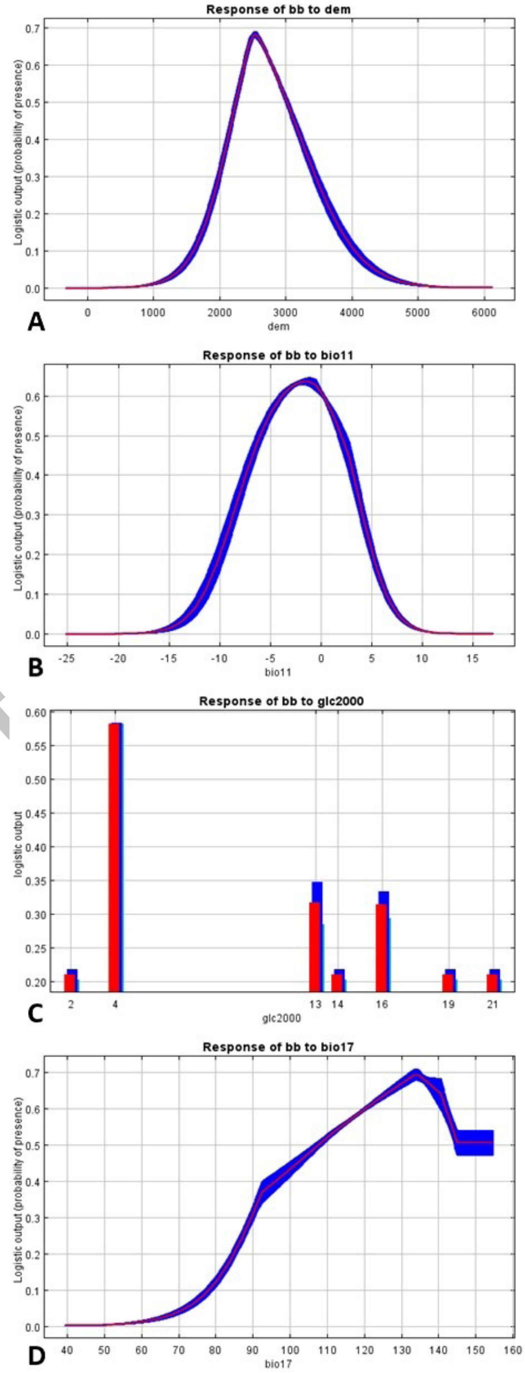

Fig. 6. Response curves of probability of presence of Asiatic black bear to (A): Elevation, (B): mean temperature of coldest quarter, (C): global land cover (D): precipitation of driest quarter. The red curves represent the mean trends while the blue shades show the mean +/- the standard deviation. In each graph, the x-axis shows the change in each environmental variable, while the y-axis shows the species' probability of presence.

preferred forest covers, and substantially avoided human settlements. Asiatic black bear eluded town proximity though substantial individual differences noted in livestock shed and crop field selection (Takahata *et al*., 2013). Deb *et al*. (2019) recorded the density of forest vertebrates dependent upon the elevation, forest cover, and climate. In consistence to our findings, they also recorded elevation, mean precipitation and temperature as key bioclimatic variables in determining the habitat suitability of Asiatic black bear.

Bashir *et al*. (2018) reported a high positive correlation of black bear with NDVI. In South Asia, the Asiatic black bear is confined to coniferous and broad-leaved forests that mostly occurred at marginal and monsoon tropics (Deb *et al*., 2019) and subalpine zones (Bashir *et al*., 2018). Shrub cover was removed by villagers either through fire or cutting, to enhance fodder production. The decades-long steady practice created large patches of grasslands and meadows. Natural derived landslides and avalanches also removed large trees and left the soil favorable for palatable grasses to grow and flourish. Many of these patches were abandoned due to change in lifestyle, reduction in fodder collection, and left open for succession. Regenerating open lands has a significant positive impact on bear habitat selection and bears attracted to these patches due to seral grasses and fleshy-fruited shrubs (Takahata *et al*., 2013).

Bear distribution and habitat use were not confined to roads or rivers. It indicated the elusive nature of black bear in the study area. Similar results have been reported by Takahata *et al*. (2013) in Japan who found a nonlinear likelihood of black bear habitat use in the context of proximity to rivers and roads. Similarly, bear distribution was relatively inconsistent with slopes in the study area (Table II). A recent study conducted by (Goursi *et al*., 2021; Zahoor *et al*., 2021) in MNP supported our findings. However, Takahata *et al*. (2013) in Japan reported that black bear was attracted more towards the steeper slopes. Slope selection could be based on grass, fruit, and seed production that could be more common in gentle slopes in the study area.

Habitat potentials

Delineating the black bear habitats along Line of Control (LoC) is easier because they exhibit sharp edges between landscape units. Line of Control is a de-facto border between Pakistan and Indian armies, nevertheless, it does not have a legal recognition or credit as an international boundary (Wirsing, 1998). LoC is a highly militarized area, on both side of the boundary, provides an estimated width of 6-10 km strip that is generally prohibited for civilian activities. Low human intereference provides opportunity to prosper ecosystems and thrive biodiversity naturally. LoC-influenced areas are characterized with dense shrubby vegetation that is significantly reduced towards the human settlements in AJ&K. Urban development in Neelum valley is restricted to the left bank of River Neelum (Sakhi-Uz-Zaman *et al*., 2019) where most of the large towns are established, roads have been built and commercial activities carried out. Areas associated with these towns are heavily degraded, fragmented, altered, and exploited for human use (Qamar *et al*., 2011; Khan *et al*., 2018; Kazmi *et al*., 2019; Waseem *et al*., 2020). Permitted reaches of bear habitat have greatly been degraded, habitats simplified by removing dead logs, trees, and shrub cover. Large-scale wood extraction, herbal collection, and grazing have turned most of the habitat unsuitable for Asiatic black bear. Kel-Naril is the least populated locality because it fulfills the needs of 70 thousand people who inhabit Kel, the largest town of AJ&K. Clear and large patches existed in natural forests of AJK and reduced traversing of the black bear through these patches. A similar trend is noted in Athmuqam, Jagran, and Tehjian localities. The right bank of the river Neelum is much protected due to the presence of LoC (Fig. 3). Fragmentation is recorded at a low scale and thus forest connectivity provides a larger habitat, home ranges, and resources to the black bear. Human impacts on natural environments are constantly increasing (Bibi *et al*., 2013) and large species are prone to decline or become extinct at an exceptional rate (Cardillo *et al*., 2005; Carroll *et al*., 2012; Ordiz *et al*., 2017). Deb *et al*. (2019) stated that 32 mammal species are extinct regionally or locally in South Asia due to habitat loss and fragmentation, and changes in land-use patterns, of course, the black bear is no exception. Similar drivers of species decline were noted in the study area. Most of the bear population is in the vicinity of LoC, on the right bank of River Neelum. Dispersal linkage among these patches could reasonably facilitate moving corridors among habitats (Duflot *et al*., 2018), allow sharing genetic makeup with isolated bear populations in AJ&K.

Black bear is well recognized as umbrella species and plays a critical role in the maintenance of ecosystems. Conservation of black bear can offer a safeguard to other sympatric species particularly in the subtropical and temperate ecosystems (Fleishman *et al*., 2000; Yamamoto *et al*., 2012; Bashir *et al*., 2018). Protection of black bear could largely rely on human activities. These beasts require larger home ranges and intact forests and connected landscapes, which are disturbed by anthropogenic activities. The focus should be given to the areas located at LoC due to protection provided by armies' conflict. These areas are not allowed to frequent visits of local people (strangers or non-local people are completely banned to get closer to the LoC). Hunting, habitat degradation, and exploitation of resources could easily be managed. These areas including the eastern border of Haveli district, southeastern areas of Leepa, and the right bank of River Neelum in Neelum valley should be declared as protected areas. The focus should also be given to protect and increase the existing connecting corridors between Athmuqam-Jagran-MNP, Athmuqam and Lawat, Moji and Lachrat forest range localities (Fig. 3). Conservation of Asiatic black bear habitat and connecting corridors will also be useful for sympatric large carnivores, particularly common leopard, grey wolf, and many of the small carnivores in the study area.

Our results revealed that temperature and precipitation are the key regulatory factors for the habitat suitability of Asiatic black bear. These variables are subject to climate change, both at regional and global scales. Pakistan is one of the major climate victims in the region. It is already experiencing environmental catastrophes, weather anomalies, shifting of precipitation (change in duration and quantity of precipitation), and temperature variations (Ashraf *et al*., 2012). Not surprisingly, these changes could severely impact the abundance and distribution of Asiatic black bear in the study area. Changes in temperature and rain patterns could also alter the plant growth, fruiting phenology, and seed ripening, which are major parts of black bear food and among key drivers that keep Asiatic black bear moving in different habitats and altitudes. Black bear may be required to adjust temporal and spatial selection patterns in retort to changing thermal constraints (Ordiz *et al*., 2017). It is questionable that the adjustment of species in a changing environment could afford the pace of climate change. A comprehensive strategy is needed to devise to cope with the drastic climate changes. Climate change could only be diverted by planting trees, conserving existing forests, and reversing the change of carbon sinks into carbon sources. A detailed study on the impact of climate change on black bear abundance and distribution is recommended in AJ&K.

Deforestation, human settlement, and agricultural extensions fragmented habitats of wild species that have a strong negative impact on their populations (Din *et al*., 2016). Fragmentation reduced home range, food availability, breeding, and escape cover particularly in large mammals such as black bear (Duflot *et al*., 2018). Connecting corridors facilitates the movement of restricted wild populations among resource patches (Duflot *et al*., 2018) and are considered among the major factors for the sustainability of biodiversity. These corridors not only provide a wind range of habitats but also a variety of food availability and thus enhance survival chances of trapped populations. Addressing corridors and habitat connectivity is gaining a premier focus in conservation and management of biodiversity (Hirzel *et al*., 2002). Mapping habitat connection and provision of connecting corridors would be a key factor in conservation planning of black bear but this task would not be easy due to ongoing LoC escalation and recurrent fire events of the forest fire.

Model application

The model revealed habitat suitability equitably well concerning black bear presence. The most suitable habitat is located at LoC and comprises protected and unprotected areas. Eastern belt of MDNP, Sharda, Dudhnial, Salkhala, and Haveli touched with LoC, having intact forests and low human disturbance. Keeping the human impact low in these areas could support a stock population of black bear. Asiatic black bear is present in low numbers in the northern belt of Neelum valley, Lachrat, and Bagh study sites where habitat is largely degraded. Habitat management in these areas is required to prevent illegal extraction of medicinal herbs, reduce the use of fuelwood and timber, lessen overgrazing pressure, and support reforestation. Habitat management practices adapted in these areas will not only enhance the black bear population but also provide connecting corridors to the adjacent bear populations in GB and Mansehra areas of Pakistan. Conservation measures taken should be in line with the needs of local people. Their subsistence on natural resources is greater and managing such conflicts could be challenging issues in the study area.

CONCLUSION

The study revealed that Asiatic black bear was distributed in southern parts of AJ&K, from Haveli district to MDNP in the extreme northeast of the State. The population density of Asiatic black bear varied significantly and bear abundance was recorded in Neelum valley along the LoC. At least 20% of the distributional range of Asiatic black bear consisted of suitable habitats for this species. Altitude, temperature, moisture, and vegetation cover significantly affect the habitat suitability of Asiatic black bear in the study area. Livestock depredation and crop-raiding by the Asiatic black bear were noted throughout its distribution range in AJ&K.

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Statement of conflict of interest

The authors have declared no conflict of interest.

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