ISSN 1819-1878

Asian Journal of Animal Sciences

http://knowledgiascientific.com

Knowledgia SCIENTIFIC
A Place to Publish Outstanding Research

OPEN ACCESS Asian Journal of Animal Sciences

ISSN 1819-1878
DOI: 10.3923/ajas.2021.19.26

Research Article
MaxEnt Modeling of Distribution and Habitat Preferences of Asiatic Black Bear in Kishtwar High Altitude National Park, Jammu and Kashmir

[1]Muzaffar A. Kichloo and [2]Neeraj Sharma

[1]Department of Environmental Sciences, Government Degree College, Thathri, District Doda, Union Territory of Jammu and Kashmir
[2]Institute of Mountain Environment, Bhaderwah Campus, University of Jammu, Bhaderwah, District Doda, Union Territory of Jammu and Kashmir

Abstract:

Background and Objective: Asiatic black bear, one of the flagship species in Kishtwar high altitude National Park is least surveyed for its current distribution, thus limiting the conservation planning and management actions at landscape level. To have first-hand information about the possible distribution and area occupancy, an attempt was made to map its spatial distribution to earmark the areas demanding specific management attention. **Materials and Methods:** Maximum Entropy (MaxEnt) algorithm was used to delineate the areas of maximum probability of black bear distribution based on selective environmental correlates. Fifty-one presence points and six environmental variables were used to generate probability distribution maps in MaxEnt. The analysis gave a deep insight into the degree of influence of environmental variables on its distribution. **Results:** The average value of 0.92 obtained for the area under receiver operating characteristic curve (AUC) substantiated that the model performed very well. The study indicated that black bears mostly preferred forested landscapes (2200-3300 m) in Kibber, Nanth, Kiyar and Renai watersheds. The land use/land cover and elevation emerged as the most critical variables to the model building with individual contribution of 48.1 and 45.2%, respectively. **Conclusion:** The results suggested that dense temperate forests, the ideal habitats of black bear mostly along the perennial streams and rivers should be given due attention in long-term conservation and planning. The area outside the park should also be included to have a better understanding of habitat requirements of the animal and its likely dispersal routes.

Key words: Modeling, MaxEnt, jackknife, Kishtwar National Park, large mammals, distribution

Citation: Kichloo M.A. and N. Sharma, 2021. MaxEnt modeling of distribution and habitat preferences of Asiatic black bear in Kishtwar high altitude National Park, Jammu and Kashmir. Asian J. Anim. Sci., 15: 19-26.

Corresponding Author: Neeraj Sharma, Institute of Mountain Environment, Bhaderwah Campus, University of Jammu, Bhaderwah, District Doda, Union Territory of Jammu and Kashmir

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

For the effective management of large mammals, knowledge about their distribution is very important so that managers and conservationists can delineate and prioritize areas for the implementation of conservation policies and practices[1]. In the face of increasing anthropogenic pressures, determining distributions is crucial for long term survival of the species[2]. Long term data on space-use and abundance are necessary, but conventional approaches like transect surveys, camera traps and non-invasive genetic sampling are cost and labor-intensive as well as time consuming[3-7]. Consequently, the conservation biologists are increasingly relying on predictive models for estimating patterns of species distribution and thereby defining conservation strategies[8-10].

Whereas a large number of statistical methods are in practice to construct species distribution models, MaxEnt was used in the current study. MaxEnt is a machine learning program that uses a statistical technique called maximum entropy which makes predictions from incomplete information[11-12]. MaxEnt models the geographic distribution of species using occurrence records and different environmental variables on the principle of a uniform probability distribution. MaxEnt models have been considered ideal for predictive performance of Species Distribution Models.

The Asiatic black bear *Ursus thibetanus,* (here onwards as black bear) sometimes also referred to as Himalayan black bear is a vulnerable species as per the International Union of Nature and Natural Resources (IUCN) red list[13] with bodyweight average of 135 kg (60-200 kg) for males and 40-125 kg for females. It has been reported to be continuously distributed through southern and eastern Asia from westward through Pakistan and Afghanistan to Baluchistan province of Iran; east to Indo-China, Korea and Japan and an isolated population in Taiwan[14]. Schaller[15] reported a widespread distribution for black bears from Korea and Russia to Indo-China and from the forests of the Himalayas below an altitude of 3,750 m west as far as Afghanistan and Iran. The Himalayan region and hills of northeast India probably holds one of the largest populations of black bear in Asia[14,16], with best-known population being reported from the Jammu and Kashmir state[16,17].

Kishtwar high altitude National Park, (here onwards as Kishtwar National Park) was notified in the year 1986 in Kishtwar district of the erstwhile state of Jammu and Kashmir. Located between 33°20 and 34°04 N and 75°40 and 76°10 E, the park initially covered an area of 1700 Km^2 (1250 Km^2 under permanent snow/glacier and 450 Km^2 under forest cover) in an elevational range of 1800 m to 6000 m. Subsequently, in an extensive demarcation exercise, all habitations, hamlets and villages from the park were excluded and park boundaries were redefined with the final area coverage of 2193 km^2. The National Park provides representative and distinct habitats for large carnivores like snow leopard, common leopard, black bear, brown bear and Himalayan fox. The current status and extent of distribution of large mammals from this region is largely unknown. The first animal survey in the protected area was however undertaken by Kichloo[18] followed by Parsa[19] and Baba[20] while, Hilaluddin and Naqash[21,22] conducted preliminary census and population/density estimates of large mammals. No more studies / exhaustive census surveys have been reported since then. The spatial extent, past distribution and current occupancy of mammals, including the black bear has not so far been recorded for the park. This study thus aimed at understanding the current distribution of black bears, identify its potential habitat and delineate such areas for further conservation and management.

MATERIAL AND METHODS

Study area: The Kishtwar National Park lies at a distance of around 70 km north of Kishtwar town on the north-eastern side of the Union Territory of Jammu and Kashmir bordering with Kargil district of Union Territory of Ladakh. It lies between 33°43 and 33°99 N and 75°65 and 76°28 E with area coverage of 2193 km^2 and elevational range of 2224 m to 6293 m (Fig. 1). The study area is characterized by vivid landscapes comprising vast and narrow valleys, rugged mountains, broken cliffs, snow-clad peaks and a vast drainage network. The wide range of habitats viz., temperate, sub-alpine, alpine and rocky outcrops support a good population of carnivores and their prey base. The Park is well drained by four major streams/rivulets i.e., Kibber, Nanth, Kiyar and Renai. Renai, the largest watershed bounds Kashmir in north-west and Ladakh in north, while Kiyar share the northern boundary with Ladakh, and, Kibber and Nanth with Paddar division of Kishtwar district in the east. Renai stream drains into Marusudar River at Marwah while Kiyar, Kibber and Nanth streams join Marusudar at Dachan. Marusudar joins river Chandrabhaga at Bhandarkot, Kishtwar and flow as river Chenab beyond this point draining Akhnoor further south towards Pakistan.

Species occurrence data: The trails within forests, streams, ridgelines, narrow valleys in different landscapes were walked for signs of black bear in the elevational range of 2200 m to

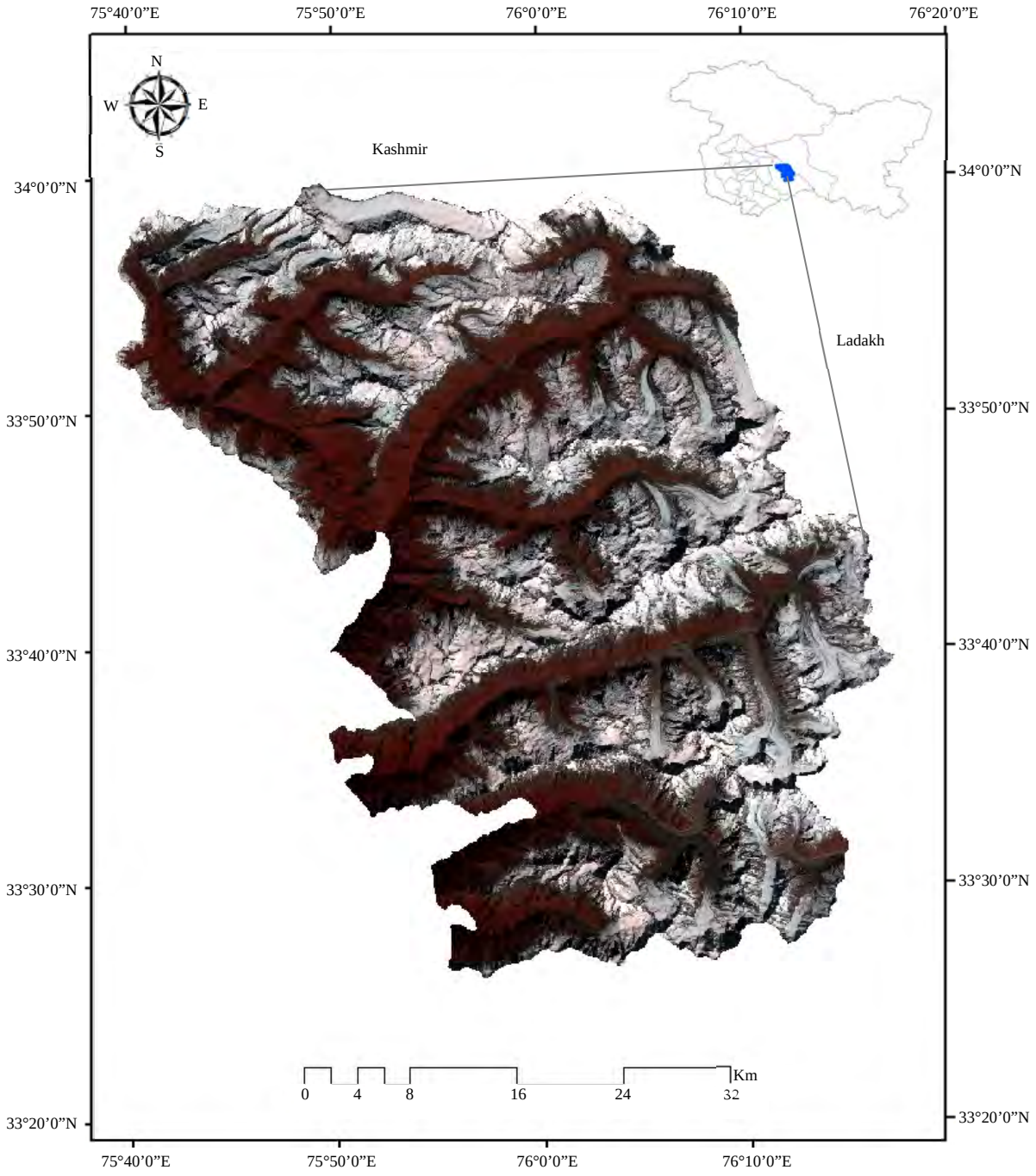

Fig. 1: False color composite of Kishtwar National Park
Source: Department of Wildlife Protection, J and K

Table 1: Pre-selected environmental variables for the Modeling process

Category	Variable	Format	Resolution	Source
Topographic	Elevation	Raster	30 m	Cartosat 1
	Slope	Raster	30 m	Cartosat 1
	Aspect	Raster	30 m	Cartosat 1
	Distance to rivers	Raster		Geofabrik
Topographic/Anthropogenic	Land use/Land cover	Raster	0.5 km	ESA
Vegetation	NDVI	Raster	30 m	Landsat 8

4800 m during the period from March to October, 2018. The direct sightings or presence signs (footprints, scats, scrapes, predation on wild and domesticated animals, etc.) were observed using binoculars and digital cameras and the geo-coordinates were recorded using Global Positioning System (GPS). Out of total 67 presence points recorded during the surveys, only 51 were used in modeling as others lie outside the park boundaries.

Environmental variables: Different environmental variables were considered as potential predictors affecting the distribution of black bears in Kishtwar National Park (Table 1). These were based on the knowledge and understanding of species in the park as well as from the existing literature. The selected variables included terrain (elevation, slope, aspect and distance to water bodies/rivers), vegetation (Normalized Difference Vegetation Index, NDVI) and land use/land cover. Distance to the roads and settlements were not used in this case as our investigations were restricted to the park boundaries and not beyond.

Modeling: MaxEnt (Maximum Entropy Modeling) version 3.4.1[11] was used to generate the potential distribution maps for black bear in Kishtwar National Park. The environmental layers, along with occurrence layer were loaded into MaxEnt as the model inputs. The presence data was divided into two sets, 75% for training and 25% for testing the model.

The model was run in ten replications using sub-sampling method with 5000 iterations and the percent contribution of each environmental variable was estimated for each iteration in MaxEnt algorithm. The Jackknife test that evaluates the importance of each environmental variable by subtracting the gain value of each variable in isolation to the total gain value with all variables was also performed. Environmental variables with highest gain value convey most meaningful information to the model.

Evaluation of accuracy of any distribution model is essential to validate models and to understand the model performance. Model was evaluated by calculating the area under the Receiver Operator Characteristic (ROC) Curve (AUC)[11,23]. As ROC (AUC) analysis is independent of both threshold setting and prevalence, it is one of the highly effective methods to assess the performance of ordinal score (presence-only) species distribution models[24-26]. AUC is derived by plotting sensitivity (the likelihood that a model correctly classifies a presence) versus 1-specificity (the probability that a model correctly classifies an absence). AUC has a specified range value of 0.5 to 1, where AUC >0.9 reveals the excellent, 0.7-0.9 the moderately useful and AUC <0.7 poor model performance, respectively.

RESULTS

The AUC value obtained for ten replicate runs was 0.922 with a standard deviation of 0.025 as reflected in Receiver Operating Characteristic (ROC) curve (Fig. 2). The

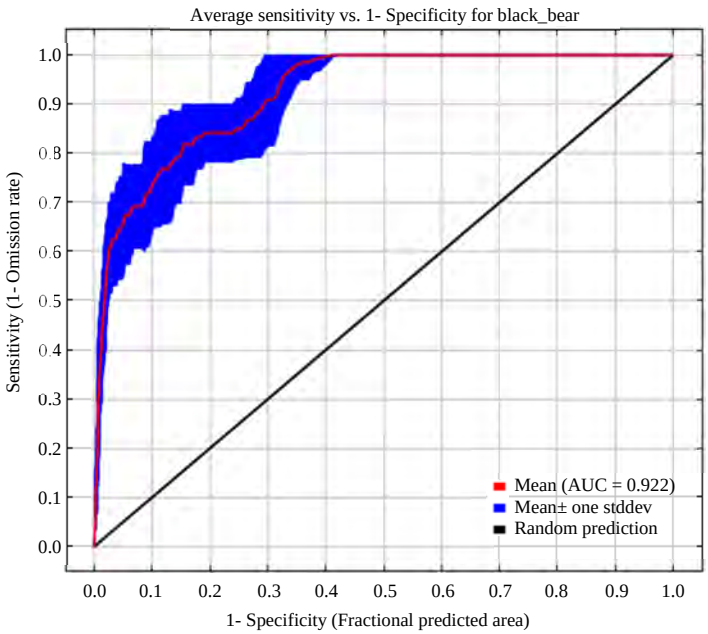

Fig. 2: ROC curves for models of black bear

higher AUC values substantiate high accuracy of model generated for predicting the distribution of black bear in Kishtwar National Park. The warmer colours (P = 1) in continuous coloured distribution map generated for the species indicate areas with high probability of the species while blue (P = 0) suggested the least likelihood (Fig. 3).

Analysis of variable contributions: While comparing the relative contributions of several environmental variables in the model, land use/land cover with individual contribution of 48% emerged as a significant factor influencing the spatial distribution of black bear in Kishtwar National Park.

It was followed by elevation (45.2%) while others viz., slope, aspect, NDVI and distance to the water body carried minuscule weightage (Fig. 4).

Likewise in Jackknife test, elevation (elev) appeared to be the prime environmental variable influencing the distribution of black bear in the park with highest gain value (Fig. 5) followed by lulc i.e., land use/landcover. The test suggested that elevation had highest gain when used in isolation, which therefore appears to have the most useful information by itself.

Habitat suitability: The probability distribution map generated using MaxEnt was imported into Q GIS[27] and

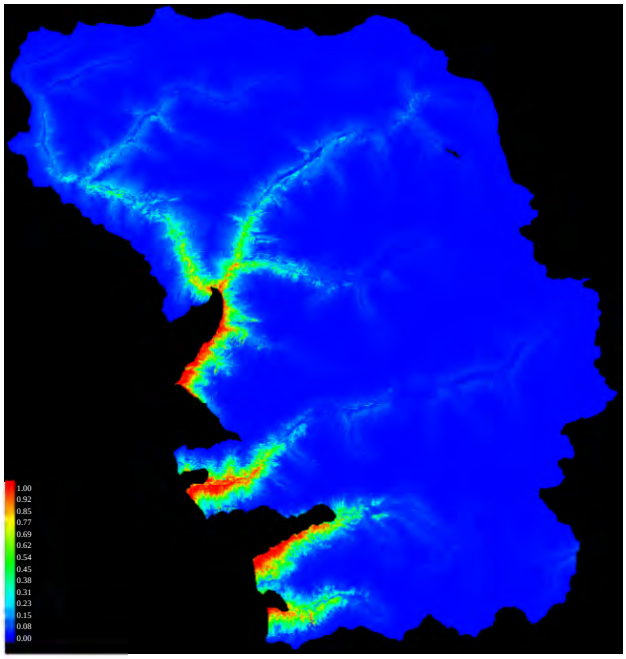

Fig. 3: Species distribution map of Black bear

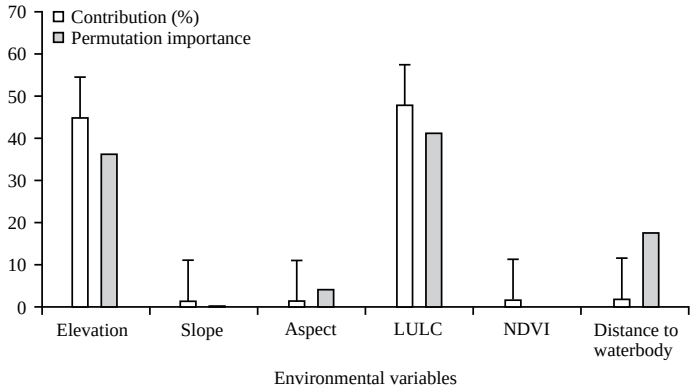

Fig. 4: Contribution of environmental variables in the model building

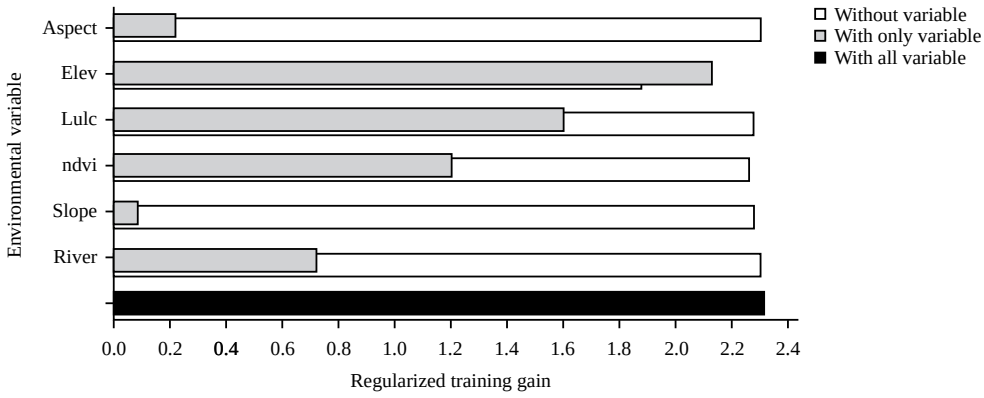

Fig. 5: Jackknife test of variable importance for Black bear in Kishtwar National Park

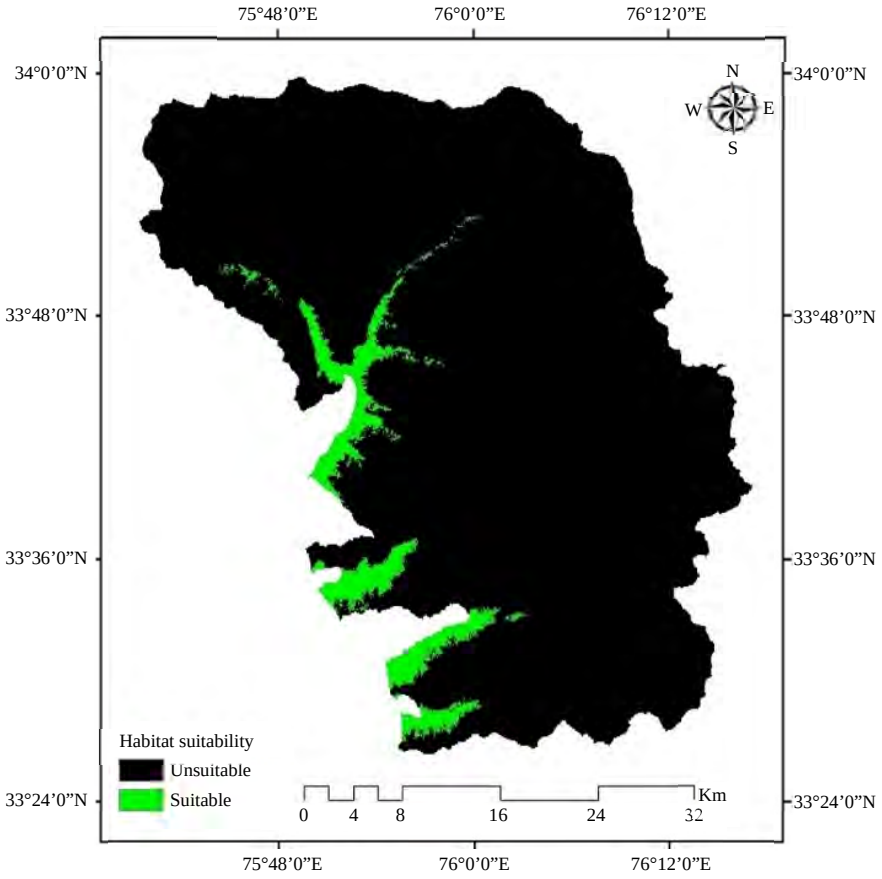

Fig. 6: Binary habitat suitability map for Black bear in Kishtwar National Park

re-classified based on the 10-percentile logistic threshold (of 0.064) to a binary suitable/unsuitable habitat map for black bear in Kishtwar National Park (Fig. 6). The suitable category included areas with environmental conditions conducive for the species to survive and vice versa. The binary habitat suitability map can serve as a valuable ingredient for setting up the conservation and management practices for black bears.

DISCUSSION

The current study was first of its kind in Kishtwar National Park where the data on mammals in general and black bear in particular is scanty[22]. The outputs produced by MaxEnt generally reflected the established facets of bear ecology and biology associated with habitat suitability. The results indicated that distribution of black bears is restricted

to lower elevations between 2200-3300 m. Garshelis and Steinmetz[13] reported black bear habitat in both coniferous and broad-leaved forested landscapes at an altitude of up to 4500 m, whereas, Bista and Aryal[28] found the distribution of black bears confined to elevation range 1400-3500 m in Annapurna Conservation Area in Nepal. The elevation is one of the most influential environmental variables which act as a limiting factor for the distribution of terrestrial carnivores by indirectly affecting the distribution through temperature[29,30]. The Jackknife test also suggested that elevation had the highest gain value, which, therefore, appears to have the most useful information by itself which is the case for black bear as well as other large mammals[29,31].

The land use/landcover emerged as a significant factor affecting the distribution of black bears in Kishtwar National Park, with maximum probability in temperate broad-leaved and coniferous forests along the major river courses of Kibber, Nanth, Kiyar and Renai watersheds. It signifies a direct relationship between the vegetation, water bodies and species distribution. Forest cover has been known to play an important role in habitat selection by black bears wherein they occupy a variety of forested areas from temperate evergreen conifers to subtropical broadleaved deciduous forests [14,28,32,33]. Liu *et al.*[34] found that the forest cover was the only significant environmental variable that positively affected black bear distribution in south-western China. Black bears are also reported to use multiple land covers as opportunistic omnivores[33,35]. Another important variable which affected the black bear habitat selection in KNP was the distance to water bodies (rivers). Water indirectly affected the black bears in two ways; first their survival and secondly, the areas close to rivers were mostly covered by forests which primarily affected their distributions. MaxEnt modeling has proven to be very effective at determining species distributions for a variety of species and localities, especially when the sample size is very small[36-38] and a suggested Species Distribution Modeling tool for black bear.

CONCLUSION

The present study investigated the spatial distribution of black bear in Kishtwar National Park. The probability distribution maps were prepared by using 51 presence points with six environmental variables in MaxEnt. The model indicated that black bear prefers the temperate broad-leaved and coniferous forests along with an elevation range of 2200-3300 m in all four watersheds. Study points out the importance of forest conservation in order to conserve black bears in KNP.

SIGNIFICANCE STATEMENT

Land use/land cover dynamics and other environmental variables help to delineate the potential and preferred habitats of a particular species on broader spatial and temporal scales. Current study describes the drivers of spatial distribution and habitat preferences of black bear, one of the key mammal species of Kishtwar National Park that many researchers were not able to explore. The maps so generated will help the park managers to prioritize their habitat conservation efforts in the park.

ACKNOWLEDGMENTS

Authors are grateful to the Department of Wildlife Protection, Govt. of Jammu and Kashmir for necessary permits and to the Wildlife Warden, Chenab Circle for providing necessary support in field surveys. The authors thankfully acknowledge the Rufford Foundation UK (Ref:18107-1) for providing the initial financial support in the surveys. The acknowledgments are also due to Rector, Bhaderwah Campus and the University of Jammu for providing the necessary support for the smooth conduct of the research work.

REFERENCES

1. Lu, C.Y., G.W., A.H. Dai and H.Y. Wei, 2012. Assessing habitat suitability based on geographic information system (GIS) and fuzzy: A case study of *Schisandra sphenanthera* Rehd. et Wils. in Qinling Mountains, China. Ecol. Model, 242: 105-115.
2. Ebrahimi, A., A. Farashi and A. Rashki, 2017. Habitat suitability of Persian leopard (*Panthera pardus* Saxicolor) in Iran in future. Environ. Earth Sci., 76: 697-707.
3. McCarthy, T.M., T.K. Fuller and B. Munkhtsog, 2005. Movements and activities of snow leopards in Southwestern Mongolia. Bio. Cons., 124: 527-537.
4. Jackson, R.M., J.D. Roe, R. Wangchuk and D.O. Hunter, 2006. Estimating snow leopard population abundance using photography and capture–recapture techniques. Wildl. Soc. Bull., 34: 772-781.
5. Janečka, J.E., B. Munkhtsog, R.M. Jackson, G. Naranbaatar, D.P. Mallon and W.J. Murphy, 2011. Comparison of noninvasive genetic and camera-trapping techniques for surveying snow leopards. J. Mammol., 92: 771-783.
6. Zeller, K.A., S. Nijhawan, R. Salom-perez, S.H. Potosme and J.E. Hines, 2011. Integrating occupancy modeling and interview data for corridor identification: A case study for Jaguars in Nicaragua. Bio. Cons., 144: 892-901.

7. Sharma, K., R. Bayrakcismith, L. Tumursukh, O. Johansson, P. Sevger, T. McCarthy and C. Mishra, 2014. Vigorous dynamics underlie a stable population of the endangered snow leopard *Panthera uncia* in tost mountains, south gobi, mongolia. PLoS ONE, 10.1371/journal.pone.0101319
8. Peterson, A.T. and C.R. Robins, 2003. Using ecological niche Modeling to predict Barred Owl invasions with implications for Spotted Owl conservation. Cons. Bio., 17: 1161-1165.
9. Araújo, M.B., M. Cabeza, W. Thuiller, L. Hannah and P.H. Williams, 2004. Would climate change drive species out of reserves? An assessment of existing reserve-selection methods. Global Change Biol., 10: 1618-1626.
10. Sánchez-Cordero, V., V. Cirelli, M. Munguía and S. Sarkar, 2005. Place prioritization for biodiversity content using species ecological niche modeling. Bio. Info., 2: 11-23.
11. Phillips, S.J., R.P. Anderson and R.E. Schapire, 2006. Maximum entropy modeling of species geographic distributions. Ecol. Modell., 190: 231-259.
12. Elith, J., S.J. Phillips, T. Hastie, M. Dudik, Y.E. Chee and C.J. Yates, 2011. A statistical explanation of MaxEnt for ecologists. Divers. Distributions, 17: 43-57.
13. Garshelis, D.L. and R. Steinmetz, 2008. *Ursus thibetanus*. The IUCN Red List of Threatened Species 2008: e.T22824A9391633.
14. Sathyakumar, S., 2001. Status and management of asiatic black bear and himalayan brown bear in India. Ursus, 12: 21-30.
15. Schaller, G.B., 1977. Mountain Monarchs: Wild Sheep and Goats of the Himalaya. University of Chicago Press, Chicago, IL., USA., ISBN-13: 9780226736419, Pages: 425.
16. Sathyakumar, S. and A. Choudhury, 2007. Distribution and Status of Asiatic black bear *Ursus thibetanus* India. J. Bom. Nat. His. Soc., 104: 316-323.
17. Charoo, S.A., L.K. Sharma and S. Sathyakumar, 2011. Asiatic black bear-human interactions around Dachigam National Park, Kashmir, India. Ursus, 22: 106-113.
18. Kichloo. N.A., 1992. Census report of Kishtwar high altitude National Park. Department of Wildlife Protection, Kishtwar, Govt. of Jammu and Kashmir.
19. Parsa, M.A., 1999. Survey of animals in Kishtwar high altitude National Park. Department of Wildlife Protection, Kishtwar, Govt. of Jammu and Kashmir.
20. Baba, M.M., 2003. Annual animal census report of Kishtwar high altitude National Park 2002-03. Chenab Division, Kishtwar, Department of Wildlife Protection, Govt. of Jammu and Kashmir.
21. Hilaluddin and R.Y. Naqash, 2006. Survey and census report of Kishtwar high altitude National Park. Chenab Wildlife Division, Department of Wildlife Protection, Govt. of Jammu and Kashmir.
22. Hilaluddin and R.Y. Naqash, 2013. Densities and population sizes of large mammals in Kishtwar high altitude National Park, Jammu and Kashmir, India. Indian For., 139: 872-878.
23. Hanley, J.A. and B.J. McNeil, 1982. The meaning and use of the area under a Receiver Operating Characteristic (ROC) curve Radiology, 143: 29-36.
24. Fielding, A.H. and J.F. Bell, 1997. A review of methods for the assessment of prediction errors in conservation presence/absence models. Enviorn. Cons., 24: 38-49.
25. Allouche, O., A. Tsoar and R. Kadmon, 2006. Assessing the accuracy of species distribution models: Prevalence, kappa and the True Skill Statistic (TSS). J. Appl. Ecol., 43: 1223-1232.
26. Peterson, A.T., M. Papes and J. Sober, 2008. Rethinking receiver operating characteristic analysis applications in ecological niche modeling. Ecol. Modell., 213: 63-72.
27. QGIS Development Team, 2020. QGIS geographic information system. Open Source Geospatial Foundation Project.
28. Bista, R. and A. Aryal, 2013. Status of the Asiatic black bear *Ursus thibetanus* in the south-eastern region of the Annapurna conservation area, Nepal. Zool Ecol., 23: 83-87.
29. Bista, M., S. Panthi and S.R. Weiskopf, 2018. Habitat overlap between Asiatic black bear *Ursus thibetanus* and red panda *Ailurus fulgens* in Himalaya. PLoS ONE, 10.1371/journal.pone.0203697
30. Watts, S.M., T.M. McCarthy and T. Namgail, 2019. Modelling potential habitat for snow leopards (*Panthera uncia*) in Ladakh, India. PLoS ONE, 10.1371/journal.pone.0211509
31. Dorji, S., K. Vernes and R. Rajaratnam, 2011. Habitat correlates of the red panda in the temperate forests of Bhutan. PLoS ONE, 10.1371/journal.pone.0026483
32. Hiller, T. L., J. L. Belant, J. Beringer and A. J. Tyre, 2015. Resource selection by recolonizing American black bears in a fragmented forest landscape. Ursus, 26: 116-128.
33. Takahata, C., N. Sadanori, K. Kirara and I. Shigeyuki, 2019. An evaluation of habitat selection of Asiatic black bears in a season of prevalent conflicts. Ursus, 24: 16-26.
34. Liu, F., M. William, G. David, Z. Xiaojian, W. Dajun, G. Ji'en and C. Youping, 2009. Spatial distribution as a measure of conservation needs: an example with Asiatic black bears in south-western China. Div. Dist., 15: 649-659.
35. Mcfadden-Hiller, J.E. and J. L. Belant, 2018. Spatiotemporal shifts in distribution of a recolonizing black bear population. Ecosphere, 10.1002/ecs2.2375
36. Hernandez, P.A., C.H. Graham, L.L. Master and D.L. Albert, 2006. The effect of sample size and species characteristics on performance of different species distribution modeling methods. Ecography, 29: 773-785.
37. Pearson, R.G., C.J. Raxworthy, M. Nakamura and A.T. Peterson, 2007. Predicting species distributions from small numbers of occurrence records: A test case using cryptic geckos in Madagascar. J. Biogeogr., 34: 102-117.
38. Baldwin, A.R., 2009. Use of maximum entropy modeling in wildlife research. Entropy, 11: 854-866.