Online ISSN: 2588-3526

Journal of Wildlife and Biodiversity

Volume 9(3): 34-47 (2025) (http://www.wildlife-biodiversity.com/)

Research

Distribution and habitat suitability modelling of the regionally endangered Common Leopard in Ayubia National Park

Majid Aijaz*, Muhammad Mushtaq, Muhammad Azhar Jameel, Muhammad Sajid Nadeem, Tariq Mahmood

Department of Zoology, Wildlife and Fisheries / Faculty of Sciences / Pir Mehr Ali Shah Arid Agriculture University Rawalpindi, Pakistan.

*Email: mmajidak0@gmail.com

Received: 11 May 2025/Revised: 21 September 2025/ Accepted: 28 September 2025/ Published online: 29 September 2025.

How to cite: Aijaz, M., Mushtaq, M., Jameel, M.A., Nadeem, M.S., Mahmood, T.(2025). Distribution and habitat suitability modelling of the regionally endangered common Leopard in Ayubia National Park, Journal of Wildlife and Biodiversity, 9(3), 34-47. DOI: https://doi.org/10.5281/zenodo.17240922

Abstract

The common leopard (*Panthera pardus*) is one of the large carnivore species distributed in different regions of the world, including the Himalayan foothills of Pakistan. The range of this species has been restricted and narrowed down due to urbanization, human intrusion, commercialization, and deforestation activities. Habitat suitability models (HSMs) are widely used for better identification of niche requirements, prioritising conservation management concerns of threatened species. The present research study aimed to determine the common leopard's current distribution range and suitable habitat within Ayubia National Park (ANP), Pakistan, and vicinity through maximum entropy (Maxent) modelling. The Common leopard was recorded at altitudes between 1367m-2972m asl with a mean elevation of 2434 ± 24.91 (m ± S.E.) during winter, while 2375m ± 40.77 during summer in the area. The average test AUC for the replicate runs was 0.95 with a standard deviation of 0.016. Habitat suitability index showed a 6% highly suitable and 11% moderately suitable habitat within the 5Km area of the national park. The most significant predictor was proximity to roads (39.3%) with the permutation importance of 28.4%, while the least significant was settlement area (7.7%) with the permutation importance of 29%. Bioclimatic variables, i.e., bio_19 (12.3% contribution, 5.2% permutation importance), bio_17 (11.5% contribution, 0.9% permutation importance), and bio_14 (9.5% contribution, 0.8% permutation importance) have the highest percentage contribution among the bioclimatic factors and DEM showed relatively low percentage contribution (2.6%) yet high permutation importance (20.2%). This model suggests that a relatively small percentage of the land (17%) is suitable for the common leopard in the area, suggesting forest conservation as a critical measure for the species' survival and/or its conservation.

Keywords: Common leopard; habitat; maxent; bioclimatic variables; conservation

Introduction

In the modern era, habitat loss and fragmentation have not only worried scientists around the world, but also emphasized the necessity of developing appropriate conservation strategies, with proper knowledge of the habitat requirements of the species in question (McKinney 2002; McDonald et al. 2008; Suleman et al., 2020). The distribution and abundance of species are linked to a number of environmental factors aiding in species management (Debinski et al., 1999). Habitat constriction, degradation, anthropogenic factors, and knowledge of species distribution play a crucial role in the conservation of a species. Mammalian carnivores are particularly susceptible to extinction due to habitat loss or human persecution because of their propensity for wide home ranges, low population densities, and relatively sluggish population growth rates (Noss et al. 1996; Gittleman et al. 2001). The common leopard (*Panthera pardus*) is one of the large carnivores belonging to cat family distributed in different regions of the world, from western and southern Africa to the Far East, Russia and Java (Stein & Hayssen, 2013). In Pakistan, the common leopard is distributed in hilly forest areas of Punjab, Khyber Pakhtunkhwa, Azad Jammu and Kashmir, Balochistan, and Sindh. It inhabits the mountains of Waziristan, Balochistan, and Sindh associated with *Acacia* scrub forest (Roberts, 1997). In the North, it is found in Margallah Hills, Murree, Abbotabad, Swat, Dir, Kaghan Valley, Kohistan, Chitral, Gilgit, and Neelum Valley in Azad Jammu & Kashmir (Akrim, 2018; Fatima, 2020; Khatoon, 2021). Such a large and diverse distribution range is the result of the high adaptability of this felid species (Akrim, 2018). Recently, the range of this species has been restricted and narrowed down due to urbanization, human intrusion and disturbance, commercial, economic developments, and deforestation. Globally, the species is now vulnerable (IUCN, 2020) and in Pakistan, it is endangered (Sheikh & Molur, 2005; Akrim, 2018; Fatima, 2020). Successful conservation and management of an endangered or threatened species requires the identification and ample understanding of suitable habitats at an environmentally meaningful scale (Fleishman et al., 2000; Doko et al., 2011). Habitat suitability models (HSMs) have been widely used in conservation and management issues for endangered species, prioritizing a better understanding of niche requirements (Ali et al., 2022). In the current study we assessed the distribution and habitat suitability of the regionally endangeredcommon leopard in Ayubia National Park to have a better understanding of common leopard distribution trends in the area.

Materials and methods

Study Area

Ayubia National Park lies between 34º00′48″N and 34º06′23″N latitude and 73º22′54″E and 73º27′15″E longitude, located in the administrative district of Abbotabad, falling within 150 km^2

of the Reserved Forests of Galiat (Khyber Pukhtunkhwa, Pakistan). Total area of ANP is 3,312ha, the altitude ranges between 1050m and 3027m above sea level, and the park receives mean annual precipitation of 1,065–1,424mm and snowfall (1-2.5m). ANP is inhabited by 31 species of mammals, some 200 species of birds, 16 species of reptiles, 3 species of amphibians, and 650 species of insects. Major mammalian species in the park include the common leopard (*Panthra pardus*), Kashmir flying squirrel (*Hylopetes fimbriatus*), giant Indian flying squirrel (*Petaurista petaurista*), Rhesus monkey (*Macaca mullata*), yellow-throated marten (*Martes flavigula*), and Murree vole (*Hyperacrius wynnei*) (Shafique & Barkati, 2010).

Species Distribution

Species distribution was assessed through a sign survey. An extensive survey of the park area was conducted, with the help of park staff/ local hunters/ wildlife enthusiasts (having experience with carnivore scats/ pugmarks), walking through or using the motorbicycle wherever possible, exploiting available herder and walking tracks, following Wemmer et al. (1996). Direct (direct field observations, camera trapping) and indirect (scats, footprints, and prey remains) signs of the common leopard were recorded during fortnightly field surveys carried out between November 2017 and October 2020. Coordinates and altitude of each sign were recorded on a sign survey sheet using a GARMIN eTrex 10 and an accurate altimeter (ver 2.2.33) mobile application and plotted on an ANP map using Arc GIS software for documenting the distribution of detected signs of species. The dead animal, footprints (Stuart & Stuart, 2015), scats (Chame, 2003), and dens of carnivore species were searched out. Scat/ faeces were identified using the available photographs and experiences of the local wildlife staff. Photographs of these signs were cross-matched and identified following Sadlier et al. (2004) and Mosheh and Ale (2009) based on shape, size, odor, the presence of footprints, location, and manner of scat deposition. Data from camera traps (Kuza Gali, Ayubia Pipeline and Church, Donga Gali, Namli Maira, Lahur Kas, Namli Waterfall, Lalazar Zoo) between November 2017 to October 2020 was obtained from the Divisional Wildlife and Forest Department of Abbotabad (KP) to assess the presence of common in ANP and adjoining areas. Finally, coordinates of camera trap data, pugmarks, and other signs (scats) were used to draw a distribution map (Akrim, 2018; Fatima, 2020) and assess habitat suitability.

Habitat Suitability Modelling (Maxent Modelling)

As the data was obtained from the Ayubia National Park and vicinity, a buffer zone of 5 km was created around the national park by using ArcGIS 10.5. Occurrence points of common leopard and two types of variables, i.e. 19 bioclimatic variables and topographical variables (Digital Elevation Model (DEM), slope, aspect), land use cover, NDVI, NDBI, NDWI, distance from land and human settlements, were used for Maximum entropy modeling.

The Shuttle Radar Topography Mission (SRTM) website was used to download the DEM layer. Slope and aspect were extracted from the DEM. The bioclimatic variable data were downloaded from the Worldclim website (http://www.worldclim.org/) for the study area with a spatial resolution of 30s. Road and human settlement data were downloaded from (https://data.humdata.org/). Distance from road and human settlement was calculated by using the Euclidean distance tool AcrGIS 10.5. Land use cover data was downloaded from the Esri website (https://livingatlas.arcgis.com/landcover/). First of all, the DEM layer was clipped according to the buffer of the national park, and its coordinate system was set as GCS_WGS_1984, and its cell size was set as 30x30 meters. All the remaining variables were masked according to the previously clipped DEM layer and their coordinate system, extent, snap raster, and cell size were as per to DEM layers. Highly correlated variables were discarded by calculating a correlation matrix using Pearson's technique, i.e., $r < 0.70$ was used in the model (Booth et al., 1994). All layers were changed to ASCII (American Standard Code for Information Interchange) format by using the Raster to ASCII tool.

The detailed methodology for the prediction of the distribution of the common leopard is shown in Figure 1. The Maxent model was used to determine the most contributing variables to the current prediction, using a maximum of 15 replicates. The Maxent work is based on available secondary data for the prediction of the suitable habitat of the species. Maxent 3.4.4 version was used with the random seed option, with 5000 iterations and 25% of the test sample size. To check the model accuracy Jackknife test, Area under the curve with training and test data were calculated. Finally distribution map of the common leopard was developed by converting the ASCII outputs to a raster. Raster was reclassified to find out the percentage of area (Ashraf et al., 2016; Ali et al., 2022). The flowchart diagram shows the procedure followed for habitat suitability modelling of common leopard (Figure 1).

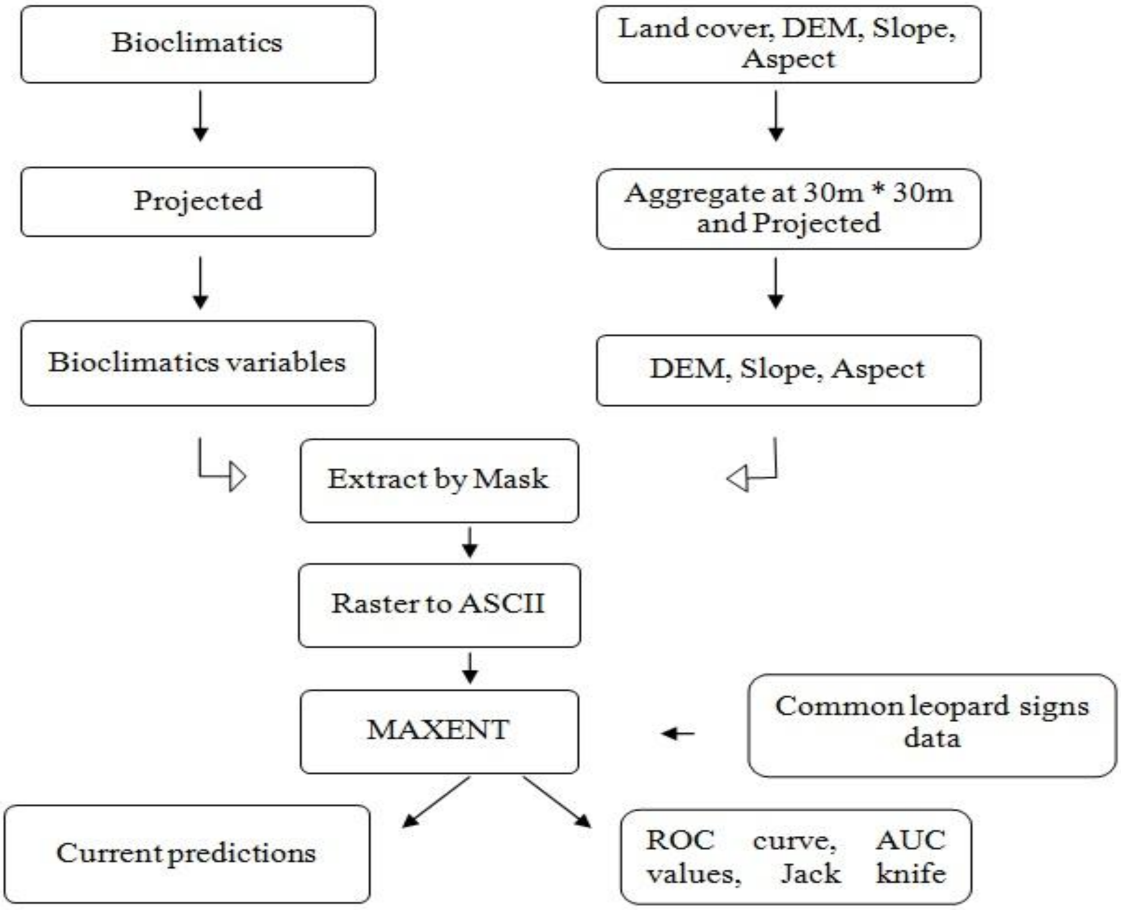

Figure 1. Flowchart for habitat suitability modelling of common leopard in Ayubia National Park.

Results

Common leopard distribution

A total of 96 common leopard (*Panthera pardus*) signs were identified, which include 66 scats, 24 pugmarks, and 6 camera trap detections. The signs were detected at altitudes ranging from 1367 m to 2972 m above sea level (asl), with a mean elevation of 2434 ± 24.91 m (m ± S.E.) during the winter season and 2375 ± 40.77 m during the summer season. Although the mean altitude was somewhat higher in the winter, statistical analysis indicated that there was no significant variation in mean elevation between the two seasons. This shows that the common leopard maintains a relatively similar elevation range throughout the year, despite probable seasonal changes in environmental circumstances or prey availability. The distribution of the common leopard in Ayubia National Park is shown in Figure 2.

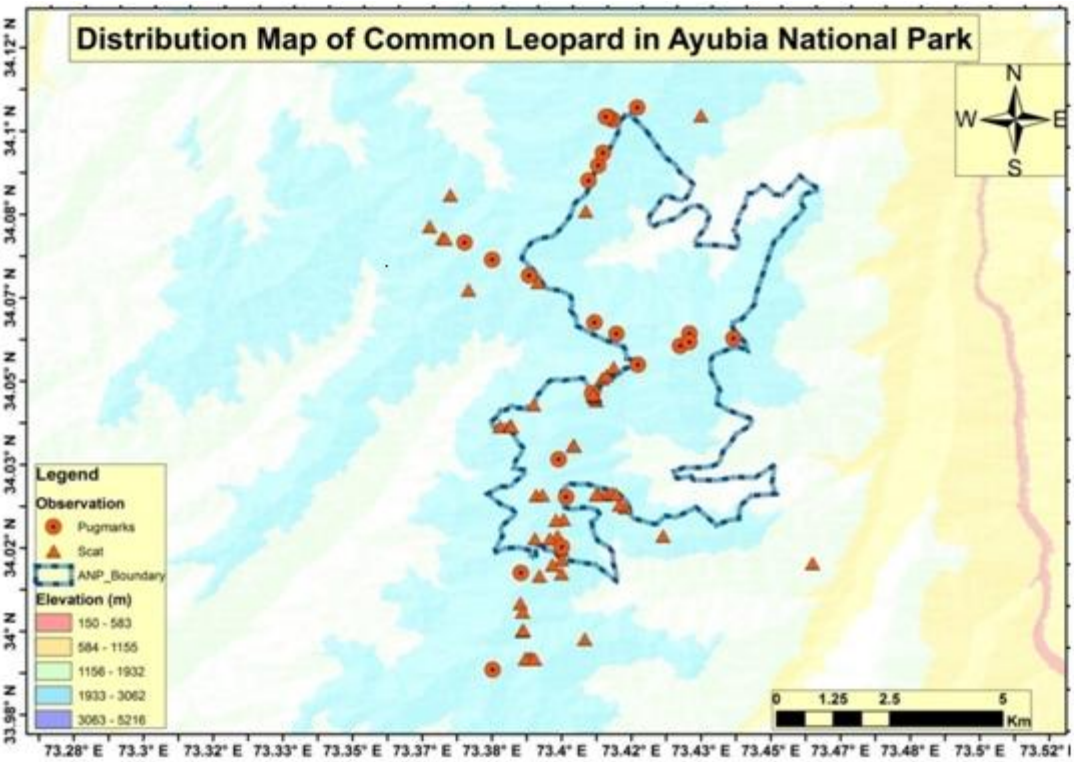

Figure 2. Map of common leopard distribution in Ayubia National Park.

Habitat suitability of Ayubia National Park for the common leopard

A habitat suitability map for the common leopard was generated using the Maxent modeling approach, categorizing habitats into three classes: highly suitable (6%), moderately suitable (11%), and non-suitable (83%) (Figure 3a). Based on current bioclimatic variables, the total area classified as suitable habitat under this model encompasses approximately 17% of the study region, which includes Ayubia National Park and its surroundings. Model performance was evaluated using the Area Under the Receiver Operating Characteristic Curve (AUC), with a mean value of 0.950 and a standard deviation of 0.016 across the replicate runs, indicating excellent predictive accuracy (Figure 3b). The high AUC value (>0.9) confirms the robustness and significance of the model. Response curves for each environmental variable are presented in Figure 4, illustrating their influence on habitat suitability. The Jackknife test results from Maxent (Figure 5) reveal the relative importance of each predictor. Among these, bio_16 (precipitation of the wettest quarter) contributed the most to model gain when used in isolation, while the variable 'road' caused the greatest decrease in gain when omitted, indicating it contains unique information not captured by other variables and plays a critical role in habitat prediction.

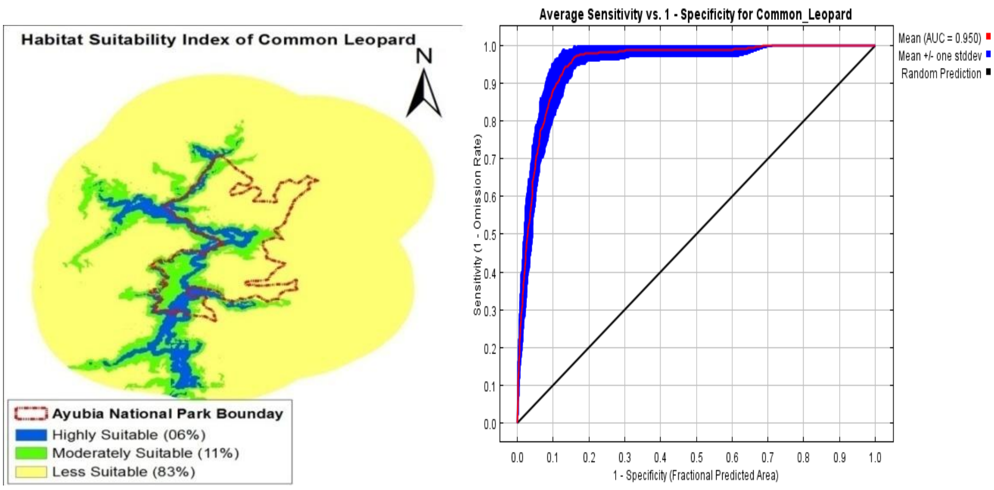

Figure 3. (A) Habitat suitability index of common leopard. (B) Receiver Operating Characteristic (ROC) curve for common leopard prediction.

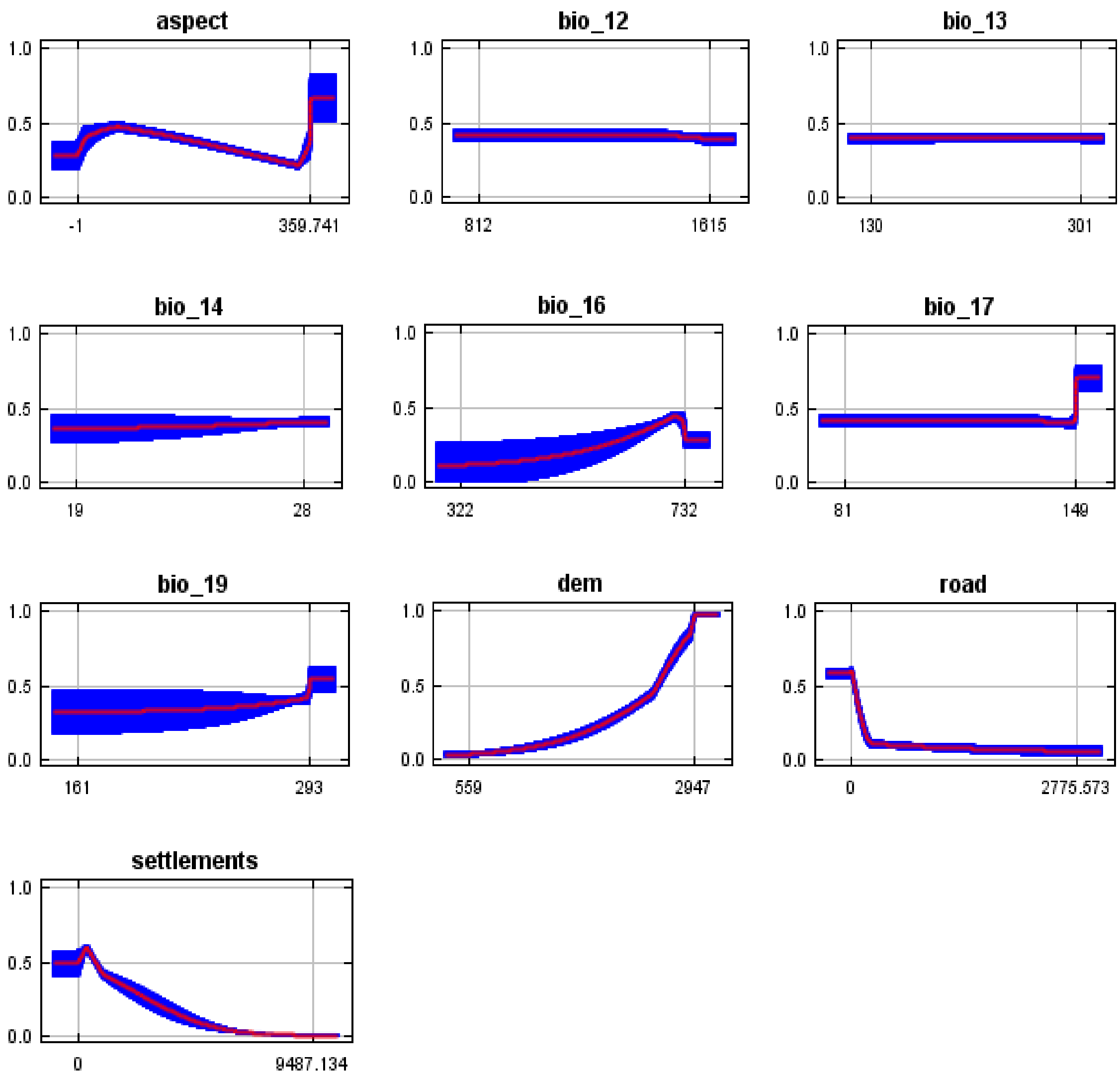

Figure 4. Leopard probability of selection response curve for each environmental covariate used in the habitat prediction model.

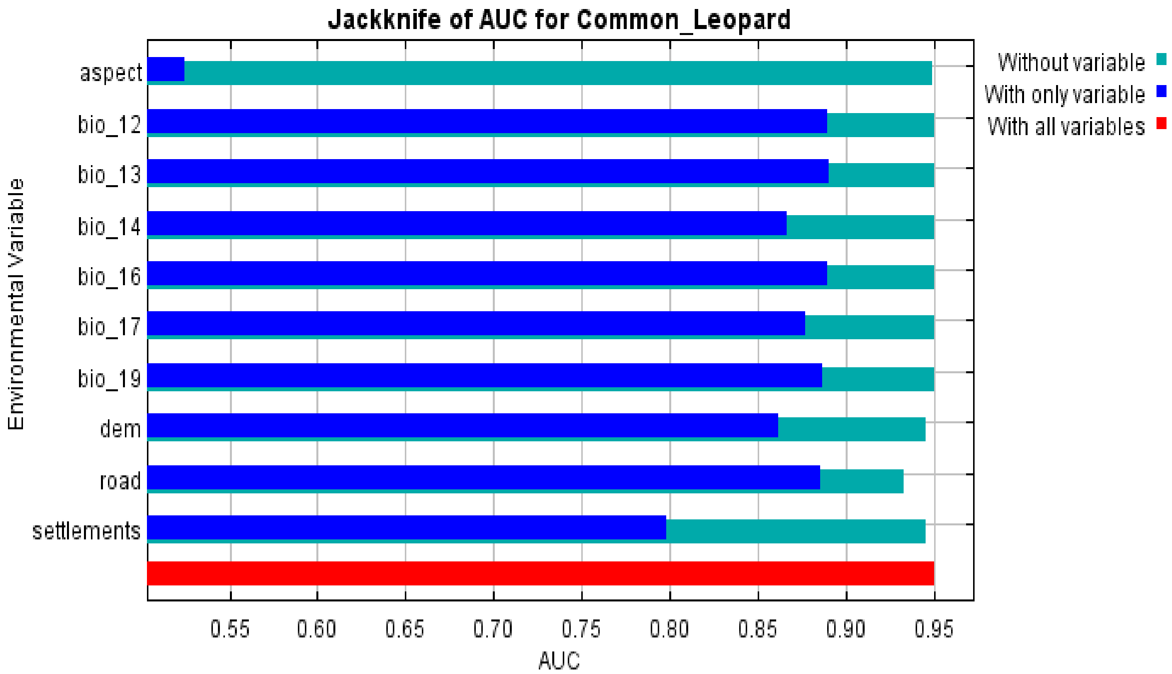

Figure 5. Jackknife of regularized training gain and area under curve (AUC) for Common leopard.

Table 1 displays the findings of the Maximum Entropy (MaxEnt) model analysis, along with the environmental variables's percentage contribution and permutation importance. The relative significance of each environmental factor in forecasting the presence of the species (or modeled condition) in the study area is revealed by these metrics.

Table 1. Percentage contribution and permutation importance of used variables.

Variable	Percent contribution	Permutation importance
road	39.3	28.4
bio_19	12.3	5.2
bio_17	11.5	0.9
bio_14	9.5	0.8
settlements	7.7	29
bio_12	7.6	0.1
bio_16	4.1	12.1
aspect	2.7	3.4
bio_13	2.7	0
dem	2.6	20.2

The most significant predictor of the modeled outcome was the variable that represented proximity to roads, which contributed the highest percentage to the model (39.3%) with the permutation importance of 28.4%. Another variable settlement area showed overall predictive power 7.7% and permutation importance of 29% suggesting that the presence or density of settlements has a significant impact on the model's AUC, even though this value may seem moderate in terms of the percent contribution. Bioclimatic variables associated with temperature, precipitation, or seasonality are represented by bio_19 (12.3% contribution, 5.2% permutation importance), bio_17 (11.5% contribution, 0.9% permutation importance), and bio_14 (9.5% contribution, 0.8% permutation importance). With bio_19—likely associated with seasonal precipitation—having the highest percentage contribution among the bioclimatic factors, these variables exhibit moderate to high contributions to the model. The explanatory power of the entire model is reduced by bio_12 (7.6% contribution, 0.1% permutation importance) and bio_16 (4.1% contribution, 12.1% permutation importance), with bio_12 exhibiting the lowest permutation importance. These findings imply that bio_16, which may be connected to temperature or precipitation extremes, has a more moderate but still significant impact on model performance than bio_12, which is probably related to annual temperature variation. In spite of its relatively low percentage contribution (2.6%), the Digital Elevation Model (DEM) demonstrated a relatively high permutation importance (20.2%), underscoring its significance in the model's functionality. This implies that elevation plays a significant role in the predictive accuracy of the model even though it cannot account for a significant amount of the variation in the modelled outcome. Elevation may have a major effect on model performance because it can interact with other environmental factors like temperature and precipitation. The land surface's orientation, or which direction it faces, is represented by aspect, which made up 2.7% of the model. Its relatively low permutation importance (3.4%), however, indicates that although certain factors, such as temperature, moisture content, and sunlight exposure, may have some bearing on the occurrence of a species, they are not a significant factor in determining its distribution within the study area. The very low percent contribution and permutation importance of bio_13, which most likely corresponds to a particular bioclimatic variable, suggest that this variable has little bearing on the model's performance or predictions.

Discussion

Common leopards are highly adaptable and may flourish in a wide range of habitats, including high-altitude forests, grasslands, and scrublands. The little fluctuation in mean elevation between seasons in the present study indicates that the species has a rather stable altitudinal distribution throughout the year. While the mean elevation was slightly higher in winter, the statistical analysis found no significant seasonal differences. This conclusion shows that the common leopard's altitudinal preference isn't significantly affected by seasonal changes in temperature or other environmental factors, such as prey or habitat cover, which might fluctuate across seasons. The leopard's high-altitude habitat, with a recorded range of above 1600 meters, is comparable with the species' known distribution in hilly forests. Akrim et al. (2018) reported the presence of the common leopard in Pir Lasura National Park at elevations ranging from 757 to 1,891 m a.s.l. The leopard was observed as a winter visitor in Margalla Hills National Park, at elevations ranging from 663 to 1,363 m a.s.l. (Fatima, 2020), while its occurrence in Murree, Kotli Sattian, and Kahuta National Park included a higher likelihood in lush green forests (Khatoon, 2021). Lovari et al. (2013) stated a wide elevation range for the common leopard between 200–3840 m a.s.l. in Asia. The observed stability in elevation shows that the species is capable of establishing stable home ranges at higher altitudes throughout the year, possibly due to the availability of resources (such as prey and shelter) that do not vary substantially between seasons at these altitudes. Higher altitudes may provide advantages such as reduced human intrusion and a more stable environment, which could benefit both predators and prey.

The altitudes documented for common leopards in the study area (ranging from 1367 m to 2972 m a.s.l.) correspond to the altitudinal gradient seen in ANP. The park's vegetation zones vary from temperate forests (below 2000 m a.s.l.) to sub-alpine and alpine meadows at higher elevations. The leopard in the study had an average elevation in both seasons that corresponds to the park's sub-alpine zone, which includes coniferous woods (Deodar and Pine) and oak woodlands. These forested areas provide crucial cover and potential prey species for leopards, including wild boar, monkeys, and other small mammals. Seasonal variations in temperature or habitat availability do not appear to have a significant impact on the common leopard's altitudinal preferences, as evidenced by the small but statistically insignificant difference in mean elevation between winter and summer. This aligns with Ayubia's year-round, generally mild climate, which varies only slightly throughout the seasons. During winter, temperatures do drop, but not to the point where leopards would have to relocate to lower elevations. Ayubia's average yearly temperature ranges from 5°C to 18°C, with winter temperatures at higher elevations being colder but still within a range conducive to leopard survival. Since leopards are known for their high degree of climate adaptation, the sub-alpine zone in ANP remains comparatively snow-covered throughout winter, though not to the extent that it would substantially affect their movement. Due to the presence of dense vegetation, such as coniferous stands and broadleaf forests providing adequate cover, leopards can maintain year-round occupancy at these elevations, probably aided by a steady supply of food and a well-organized ecosystem. Leopards find plenty of cover and shelter in these mid- to high-elevations during summer, which is characterized by moderate temperatures and increased vegetation growth.

Mountainous regions were identified as crucial habitats because of the strong correlation between leopard habitat and moderate slopes, as well as areas of plantations and natural land cover, while avoiding transformed landscapes (McManus et al., 2022). According to the findings of another study, the most important factors for predicting the presence of Persian leopards in the study area were topographic roughness, annual precipitation, vegetation/cropland composition, and distance to rivers (Kaboodvandpour et al., 2021). These findings suggest how a region's topography and environmental conditions can affect species distribution. In the current study, roads and settlements appeared to be the most significant factors influencing species distribution or the modeled outcome, with the highest percent contribution and significant permutation importance (28.4%). Ecologically, roads are often linked to habitat fragmentation, human activity, and landscape changes—all of which can have a substantial impact on species distribution. This aligns with ecological research emphasizing how roads alter habitat connectivity, increase disturbance, and facilitate the spread of invasive species. Similarly, despite having a relatively small percent contribution, settlements showed a high permutation importance (29%), indicating that patterns of human settlement are crucial in determining the spatial distribution of the species or environmental conditions. This finding is consistentThis finding is consistent with ecological studies emphasizing how human settlements and infrastructure development significantly influence species distribution by fragmenting habitats and modifying landscape permeability. Although these variables have moderate contributions in the model, their high permutation importance underscores their critical role in shaping species occurrence. Conversely, bioclimatic variables such as bio_17 (temperature of the driest quarter) and bio_19 (precipitation of the coldest quarter) exhibited lower permutation importance, suggesting that they exert a moderate influence on habitat suitability. This indicates that, while climate factors do impact species distribution, anthropogenic landscape features—like roads and settlements—play a more dominant role in defining the model's predictive capacity. Interestingly, elevation (DEM) contributed less in terms of percent importance but showed considerable importance in improving model performance, highlighting its relevance for high-altitude habitat use. Variables such as aspect and bio_13 (precipitation of the warmest quarter) demonstrated limited influence, with minimal contribution and negligible effect on the model's accuracy. Overall, these results emphasize that in the context of Pakistan's mountainous and forested landscapes, physical infrastructure and land-use patterns are the primary determinants of common leopard distribution, offering crucial insights for conservation planning and landscape management.

Conclusions

According to the Maxent analysis, the main factors influencing the model's predictions are roads and settlements. Roads account for the largest portion of the variance in the species distribution, and the removal of settlements has the biggest impact on the model's performance. Despite their moderate contributions to the model, bioclimatic variables like bio_19 and bio_17 have a lower permutation importance, indicating that they may interact with other factors but have less of an impact on the model's performance than habitat-related variables. Furthermore, even though DEM contributes less to the explanation of the species' distribution, it significantly enhances the model's performance. Aspect and bio_13 are two examples of variables that have little effect on the overall performance of the model and may be eliminated in subsequent analyses in order to simplify it. The altitudinal distribution and habitat suitability model results emphasize how crucial high-elevation habitats are for common leopards in ANP, round the year. These habitats provide the species with favorable conditions, such as abundant prey, dense vegetation, and less human interference. The persistence of this elusive predator in the park can be ensured focusing on conservation efforts through preserving important habitats and reducing human encroachment by realizing the main environmental factors influencing leopard distribution.

Acknowledgments

We cordially appreciate the effort and support of the wildlife department in Ayubia National Park for data collection during the study period.

References

Akrim, F. (2018). *Resource partitioning among sympatric carnivore species at Pir Lasura National Park, Azad Jammu & Kashmir, Pakistan* (Doctoral dissertation, PMAS-Arid Agriculture University, Rawalpindi).

Akrim, F., Mahmood, T., Nadeem, M. S., Andleeb, S., & Qasim, S. (2018). Spatial distribution and dietary niche breadth of the leopard Panthera pardus (Carnivora: Felidae) in the northeastern Himalayan region of Pakistan. *Turkish Journal of Zoology*, *42*(5), 585-595.

Ali, U., Ahmad, B., Minhas, R. A., Kabir, M., Awan, M. S., Khan, L. A., & Khan, M. B. (2023). Habitat suitability modeling of Asiatic black bear (Ursus thibetanus) in Azad Jammu and Kashmir, Pakistan. *Pakistan Journal of Zoology*, *55*(3), 1273.

Ashraf, U., Ali, H., Chaudry, M. N., Ashraf, I., Batool, A., & Saqib, Z. (2016). Predicting the potential distribution of Olea ferruginea in Pakistan incorporating climate change by using Maxent model. *Sustainability*, *8*(8), 722.

Booth, G. D., Niccolucci, M. J., & Schuster, E. G. (1994). Identifying proxy sets in multiple linear regression: an aid to better coefficient interpretation.

Chame, M. (2003). Terrestrial mammal feces: a morphometric summary and description. *Memórias do Instituto Oswaldo Cruz*, *98*, 71-94.

Debinski, D. M., Kindscher, K., & Jakubauskas, M. E. (1999). A remote sensing and GIS-based model of habitats and biodiversity in the Greater Yellowstone Ecosystem. *International Journal of Remote Sensing*, *20*(17), 3281-3291.

Doko, T., Fukui, H., Kooiman, A., Toxopeus, A. G., Ichinose, T., Chen, W., & Skidmore, A. K. (2011). Identifying habitat patches and potential ecological corridors for remnant Asiatic black bear (Ursus thibetanus japonicus) populations in Japan. *Ecological Modelling*, *222*(3), 748-761.

Fatima, H. (2020). *Diet Composition and Niche Breadth of Sympatric Carnivores of Margalla Hills National Park, Islamabad, Pakistan* (Doctoral dissertation, PMAS-Arid Agriculture University, Rawalpindi).

Fleishman, E., Murphy, D. D., & Brussard, P. F. (2000). A new method for selection of umbrella species for conservation planning. *Ecological applications*, *10*(2), 569-579.

Gittleman, J. L. (Ed.). (2001). *Carnivore conservation* (Vol. 5). Cambridge University Press.

Kaboodvandpour, S., Almasieh, K., & Zamani, N. (2021). Habitat suitability and connectivity implications for the conservation of the Persian leopard along the Iran–Iraq border. *Ecology and Evolution*, *11*(19), 13464-13474.

Khatoon, R. (2021). *Niche Overlap and Conservation of Sympatric Carnivores Inhabiting Murree Kahuta Kotli Sattian National Park, Pakistan* (Doctoral dissertation, PMAS-Arid Agriculture University, Rawalpindi).

Lovari, S., Ventimiglia, M., & Minder, I. (2013). Food habits of two leopard species, competition, climate change and upper treeline: a way to the decrease of an endangered species?. *Ethology Ecology & Evolution*, *25*(4), 305-318.

McDonald, R. I., Kareiva, P., & Forman, R. T. (2008). The implications of current and future urbanization for global protected areas and biodiversity conservation. *Biological conservation*, *141*(6), 1695-1703.

Mckinney, M.L. (2002). Urbanization, biodiversity, and conservation. *BioScience*, *52*, 883-890.

McManus, J., Schurch, M. P., Goets, S., Faraut, L., Couldridge, V., & Smuts, B. (2022). Delineating functional corridors linking leopard habitat in the Eastern and Western Cape, South Africa. *Conservation*, *2*(1), 99-121.

Molur, S. (2003). Status and Red List of Pakistan's Mammals, based on conservation assessment and management plan for mammals. IUCN, Pakistan.

Noss, R. F., Quigley, H. B., Hornocker, M. G., Merrill, T., & Paquet, P. C. (1996). Conservation biology and carnivore conservation in the Rocky Mountains. *Conservation Biology*, *10*(4), 949-963.

Roberts, T. J. (1997). The Mammals of Pakistan Oxford University Press. *New York*.

Sadlier, L. M., Webbon, C. C., Baker, P. J., & Harris, S. (2004). Methods of monitoring red foxes Vulpes vulpes and badgers Meles meles: are field signs the answer?. *Mammal review*, *34*(1-2), 75-98.

Shafique, C. M., & Barkati, S. (2010). Mammalian fauna of Ayubia National Park district Abbottabad Khyber-Pukhtoonkhwa province Pakistan. *International J. Biol. Biotech*, *7*(4), 455-461.

Stein, A. B., & Hayssen, V. (2013). Panthera pardus (Carnivora: felidae). *Mammalian Species*, *45*(900), 30-48.

Stein, A. B., Athreya, V., Gerngross, P., Balme, G., Henschel, P., Karanth, U., ... & Ghoddousi, A. (2020). Panthera pardus (amended version of 2019 assessment). *The IUCN red list of threatened species*, *2020*, e-T15954A163991139.

Stuart, C., & Stuart, M. (2015). *Stuarts' field guide to mammals of southern africa: including Angola, Zambia & Malawi*. Penguin Random House South Africa.

Suleman, S., Khan, W. A., Anjum, K. M., Shehzad, W., & Hashmi, S. G. M. (2020). Habitat suitability index (HSI) model of Punjab urial (Ovis vegnei Punjabiensis) in Pakistan.

Wemmer, C., Kunz, T. H., Lundie-Jenkins, G., McShea, W. J., Wilson, D. E., Cole, F. R., ... & Foster, M. S. (1996). Measuring and Monitoring Biological Diversity—Standard Methods for Mammals. *Mammalia n sign.*

Wolf, M., & Ale, S. O. M. (2009). Signs at the top: habitat features influencing snow leopard Uncia uncia activity in Sagarmatha National Park, Nepal. *Journal of Mammalogy*, *90*(3), 604-611.