HABITAT OVERLAPS BETWEEN ASIATIC BLACK BEAR (*Ursus thibetanus*) AND RED PANDA (*Ailurus fulgens*) IN DHORPATAN HUNTING RESERVE, NEPAL

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Submitted to

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May 2023

DECLARATION

I hereby declare that the work presented in this thesis has been done by myself and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

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This is to recommend that the thesis entitled "Habitat overlap between Asiatic black bear (*Ursus thibetanus*) and Red panda (*Ailurus fulgens*) in Dhorpatan Hunting Reserve, Nepal" has been carried out by Mr. Krishna Tamang for the partial fulfillment of Master's Degree of Science in Zoology with special paper Ecology and Environment. This is his original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institution.

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LETTER OF APPROVAL

On the recommendation of supervisor Assoc. Prof., Dr. Hari Prasad Sharma, this thesis submitted by Mr. Krishna Tamang entitled "Habitat overlap between an Asiatic black bear (*Ursus thibetanus*) and Red panda (*Ailurus fulgens*) in Dhorpatan Hunting Reserve, Nepal" is approved for the examination in partial fulfillment of the requirements for Master's Degree of Science in Zoology with special paper Ecology and Environment.

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CERTIFICATE OF ACCEPTANCE

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVATIONS

Abbreviated form	**Details of Abbreviations**
ACA	Annapurna Conservation Area
AUC	Area Under Curve Receiver Operating
CRS	Coordinate References System
DHR	Dhorpatan Hunting Reserve
DNPWC	Department of National Parks and Wildlife Reserve
GIS	Geographical Information System
GPS	Global Positioning System
IUCN	International Union for Conservation on Nature
KCA	Kanchenjunga Conservation Area
LNP	Langtang National Park
MaxEnt	Maximum Entropy Modeling
MBNP	Makalu Barun National Park
QGIS	Quantum Geographic Information System
RNP	Rara National Park
ROC	Receiver Operating Characteristics
SDM	Species Distribution Modeling

ABSTRACT

The Asiatic black bear and Red panda are considered as vulnerable and endangered species, respectively, under the IUCN Red list of threatened species. Assessing the habitat is crucial in managing the population of wild life and formulating policies for their protection. This study identified the current habitat status of both Asiatic black bear and Red panda in Dhorpatan Hunting Reserve (DHR) by using MaxEnt modeling with bioclimatic variables, anthropogenic variables (Roads, Settlement, Water Bodies, Forest), topographic variables (Aspect, Slope). The most preferred geographic area of both the species was highly dense forest near the water resources. The model identified potential suitable habitat of 265 km^2 for Asiatic black bear and 201 km^2 for Red panda, respectively, under only climatic variables. In addition, the model predicted 256 km^2, 196 km^2 for Asiatic black bear and Red panda, respectively, under both the climatic and other variables. Both species used 196 km^2 overlapped potential suitable area in case of only bioclimatic variables while 162 km^2 potential suitable area overlapped for both climatic and others variables. The Asiatic black bear was observed to have more suitable habitat than Red panda in DHR. The climatic model relies on several key variables to predict habitat overlap between Asiatic black bears and Red pandas in DHR. These variables include Mean Diurnal Range (BIO_02), Mean Temperature of Driest Quarter (BIO_09), Precipitation of Driest Month (BIO_14), and Precipitation Seasonality (Coefficient of Variation) (BIO_15). Additionally, other variables such as Forest coverage, Distance to Roads, Distance to Settlement, Distance to Water body, Aspect, and Slope as significant contributors to habitat overlap in the area. The habitat of Asiatic black bears are greatly affected by how close they are to Water body and Ground cover. In a similar way, the habitat where Red pandas live in the DHR are strongly influenced by how close they are to Human settlements, Water body, and the quality of the Ground cover. The study shows that Asiatic black bear and Red panda prefers living in areas that have lots of Ground cover and near to Water body. This study provides information on potential distribution of Asiatic black bear and Red panda along with the influence of anthropogenic factors on their distribution. In addition, this study can provide baseline information to develop a site-specific conservation action plan.

1. INTRODUCTION

1.1. Background

A species' habitat provides protection, resources, and breeding location, which are crucial in determining its range, abundance, and environmental niche, all of which play significant roles in conservation efforts (Johnson et al. 2009). The probability of species' habitat use can be determined by applying the resources selection function, which involves mapping the preferred resource units of the animals (Symondson, 2002). Habitats of wildlife may vary with season, land use, plant composition, and population status (Korschgen, 2016). An ecological community is a collection of various populations of species that interact directly or indirectly within a specific geographical region, and in simpler terms, it refers to a group of organisms living together in a specific area and interacting with one another in various ways (Agrawal et al. 2007).The relationships between different species are fundamental to numerous characteristics and ecosystem function, including the cycling of nutrients and structure of food webs (Harrison & Cornell, 2008). The type and intensity of these interactions can differ based on a variety of factors, such as the evolutionary history of the species involved and the environmental condition of the ecosystem in which they exist (Harrison & Cornell, 2008). This existence in the same habitat forces them co-exist and share common resources (Su et al. 2021a). The niche overlap describes a situation in which two or more species share certain ecological resources, such as foraging space, or soil type, either partially or completely (Cornell, 2006). This phenomenon is significant in community ecology as it is believed to play a key role in determining the number and types of species that can coexist within a given community (Cornell, 2006). Not all, but some species have habitat overlap due to similar food habitat.

Species Distribution Modeling (SDM) is a method that predicts and maps the current or possible geographic range where a particular species can be found (Pearson 2010). SDM predicts and maps the actual or potential geographic distribution of a species by considering the environmental conditions of locations where the species is known to exist (Philips et al. 2001). SDM generate spatial forecasts that indicate the appropriateness of various locations for a specific species, community, or overall biodiversity (Hirzel et al 2006). The accurate selection of environmental variables used in the SDM model is considered crucial by some researchers, as it can impact the success of interpreting habitat suitability distribution (Mac Nally, R 2000).

The Asiatic back bear (*Ursus thibetanus*) is one of the largest species of mammals found in Asia (Yadav et al. 2019). It is adapted for arboreal feeding, with relatively heavy front quarters and short curved claws providing support for frugivorous feeding habit (Mattson et al. 2022). The Asiatic black bear can be found in different environments such as forest with broad leaves or coniferous trees, and can live at various altitudes up to 4300 m above sea level (Sathyakumar et al. 2013). During spring, this species consumes succulent plants like shoots, forbs, and leaves, while in summer, they rely on insects from trees and shrubs that bear fruits, transitioning to nuts in autumn, and also engaging in scavenging on carcasses (Huygens et al. 2003). Asiatic black bears in temperate forests mostly rely on the fruits of woody plants (trees, bushes, or vines) in the fall to store up enough fat for winter denning (hibernation) (Schaller et al. 1989). These bears consequently prefer to concentrate their activity in areas having abundant feeding resources such as oak and corn, beechnuts, walnuts, hazelnuts, or stone pine seed (Schaller et al. 1989). Due to their sensitivity to habitat changes, Asiatic black bears are regarded as environmental indicators (Beeman, 1975). Asiatic black bears also contribute to the ecosystem by acting as seed dispersers (Sathyakumar & Viswanath, 2003). Despite such conditions, Asiatic black bear is threatened globally due to anthropogenic activities such as Rhododendron (*Rhododendron* spp.), Oak (*Quercu s*spp*.),* Maple (*Acer* spp.), Bamboo (*Arudinaria* spp.) and broad leaves utilization for daily life (Zahoor et al. 2021). The current habitat of the species is declining due to many anthropogenic threats, and also its population is declining globally and is currently listed as Vulnerable under IUCN Red List of Threatened Species (Garshelis & Steinmetz 2020).

The Red Panda is divided into two subspecies, *Ailurus fulgens fulgens* and *A. f. styani*, which inhabit distinct regions. The first sub-species thrives in Nepal, India, Bhutan, Myanmar, and parts of China, dwelling in bamboo-rich temperate forests (Roberts & Gittleman, 1984). On the other hand, the second subspecies is located in southwestern China's Sichuan and Yunnan provinces, with the Nujiang River serving as the geographical boundary that separates them (Glatston 1994). Red pandas are territorial species and prefer to live alone, except during the breeding season (Yonzon, 1989). Red pandas experience high levels of stress when kept in captivity, leading to reduced reproductive behaviors that are largely influenced by precipitation (Maharjan et al. 2023).

At night, they typically sleep in trees and use their urine to mark their territory at dusk. Throughout the daytime, they engage in the activity of prey and attend to their personal hygiene in a manner suggestive of feline behavior. Red pandas also communicate through whistling and twittering sounds (Helmenstine et al. 2021). The Red panda preferred fir-jhapra bamboo growths beneath the canopy, and they tend to prefer altitudes ranging from 2800 to 3900 m (Yonzon & Hunter 1991). The distribution and abundance of bamboos are influenced by various factors, including changes in land use, grazing by livestock, collection for livestock feed and human needs such as house construction (Schaller et al. 1989). The Red panda population is decreasing as a result of human activities such as habitat fragmentation, habitat loss, illegal hunting and illegal poaching as well as other anthropogenic pressure caused by humans (Kappelhof & Weerman 2020). Due to such threats along with declining population, the species is protected under national and international law (Su et al. 2021a).

Asiatic black bear and Red panda are sympatric mammal species both found in forest in same habitat (Su et al. 2021b). They are mostly found in highly dense canopy area far from Human settlement in DHR (Regmi et al. 2023). Distribution of these species depends upon the availability of food, habitat resources, and anthropogenic pressure (Panthi et al. 2012). High anthropogenic impacts that result in the loss of bamboo could potentially harm the survival of Red panda, as they heavily rely on it as a food source (Sharma et al. 2014a). In Nepal, both the species are categorized as an endangered mammal by national red list series of Nepal (Jnawali et al. 2011). In DHR, both the species are highly threatened by anthropogenic activities (Regmi et al. 2023). Thus a systematic study of potential habitats of these two sympatric species is necessary to ensure their long term conservation in DHR.

1.2. Objectives

General Objective

The general objective of the study was to identify the suitable habitat of Asiatic black bear and Red panda in DHR, Nepal.

Specific Objectives

The specific objectives of the study were:

i. To identify the suitable habitat of Asiatic black bear and Red panda in DHR.

ii. To assess the habitat, overlap between Asiatic black bear and Red panda in DHR

1.3. Rationale of the study

The Asiatic black bear and Red panda are two of the threatened species both at global and national level facing population decline due to various human induced factors, such as the presence of cattle herders and dogs in the area during the monsoon Red panda birth season (Yonzon, 1989; Reid et al. 1991). In Nepal, both species are protected by the National Parks and Wildlife Conservation Act 1973. Both species are considered keystone species, playing critical roles in maintaining the balance and functioning of the ecosystem. Studying their habitat overlaps will provide valuable insights into the interconnectedness of these species and their dependence on shared resources. Understanding the distribution and ecological significance of these species is crucial for their conservation and the overall health of the ecosystem they inhabit. The DHR area experiences high human presence, which can significantly affect the behavior and distribution of these species (Regmi et al. 2023). This study investigated the distribution of Asiatic black bear and Red panda in DHR and assesses the suitable habitat of these species under both bioclimatic and anthropogenic variables to provide crucial insights for effective conservation planning, species management in DHR. By using MaxEnt modeling, researchers can gain a better understanding of the factors that cause the Asiatic black bear and Red panda habitats to overlap. They can also study how these species are distributed across different areas and how their populations change over time. The information obtained from this research is crucial for developing effective conservation strategies to protect both the Asiatic black bear and Red panda populations in the long run.

2. LITERATURE REVIEW

2.1. Distribution of Asiatic black bear and Red panda

Globally threatened Red panda is found in isolated high mountain's bamboo- forest patches in Nepal. This species is recorded from the Himalayan region, specifically inhabiting temperate forests with plentiful bamboo, at altitudes ranging from 2200 to 4500 m (Glatston et al. 2015). Red panda signs in Simsime community forest were 1.36/km within the altitudinal range of 2800 m to 3400 m which shows the existence of Red panda in Kanchenjunga Conservation Area (Lama, 2019). Research held on six blocks of DHR was Red panda was spotted at an elevation of between 2800 to 4000 m (Panthi et al. 2012). Survey held in 2009 at DHR resulted that Red panda pellet groups were observed from 3,000 to 3,600 m. Frequency of pellet groups increased markedly from 3,000 to 3,500 m then declined sharply at higher elevations (Sharma & Belant, 2009). During a comprehensive survey of line transects conducted within Langtang National Park, the collected a total of 161 Red panda fecal pellets from elevations ranging between 3000m and 3600m (Thapa & Basnet 2015). The study conducted in the Jumla district revealed that Red pandas were distributed within an elevation range of 2800 to 3200 m, with preference for a habitat between 2900 to 3000 m (Bhatta et al. 2014). Red pandas were confirmed in the Gaurishankar Conservation Area, with a patchy distribution observed, indicated by the presence of droppings at elevations of 3000 m but declining sightings as elevation reached 3600m (Thapa et al. 2011).

The Asiatic black bear has been sighted in various mountain protect ted areas throughout Nepal, such as DHR, Kanchenjunga Conservation Area, and Annapurna Conservation Area as well as National Parks like Makalu Barun, Sagarmatha, Langtang, Shivapuri Nagarjun, Rara and Khaptad, while several district including Dhading, Dadekdhura, Bajura, and Myagdi have also reported its presence; the species is known to inhabit elevations ranging from 1400 to 4000 m (Jnawali et al. 2011). The KCA, LNP had the highest incidence of conflict between human and Asiatic black bears (Stubblefield & Shrestha, 2007). The conflict between human and Asiatic black bear were more severe in areas located near the habitat of Asiatic black bear, specifically in the Himalayas and hills of Northeast India, within an elevation range of 1800 to 2200 m in Kashmir (Sathyakumar et al. 2013). The records indicate that the Asiatic black bear was observed at elevations ranging from 1600 to 3200 m, and was predominantly found in areas with dense forest canopies at higher altitudes in the ACA (Bista & Aryal, 2013). Asiatic black bear claw marks were predominantly found in broadleaf coniferous forest at the elevation between 1700 and 2200 m, and their presence seemed to be linked to the availability of food (Steinmetz & Garshelis, 2008b). Not only in Nepal, the signs of Asiatic black bears were observed in the Kaghan Valley of Pakistan at elevations ranging from 1500 to 2790 m (Ali et al. 2022). In this study these both species are presence in elevation range of 2657 m to 3674 m within the DHR.

2.2. Diet composition of Asiatic black bear and Red panda

The Red panda is sole representative of *Ailuridae* family in the order carnivore. It has adopted on herbivorous diet, specializing in bamboo (Bleijenberg & Nijboer, 1989). Within the DHR, six plant species were identified, with *Arudinaria* spp. being found in significantly higher proportions compared to other species (Panthi et al. 2012). Bamboo was the main source of food for the Red panda in both pre and post-monsoon seasons, while the occurrence of non-bamboo foliage was found to be higher in the post-monsoon season than in the pre-monsoon season (Sharma et al. 2014b). The Red panda's diet consists of various components, with *Arudinaria aristata* being the most consumed, while *Sorbus microphylla* being the least consumed (Pradhan et al. 2001). It has been observed that the dietary composition of captive Red pandas differs from that of their wild Red pandas (Eriksson et al. 2010). Red pandas mostly eat jhapra leaves, but they also have seasonal foods like Sorbus fruits and mushrooms in late summer and autumn, and they include jhapra and raate shoots in their diet during spring and summer (Yonzon & Hunter, 1991)

A total of 21 different types of food items were identified from Asiatic black bear scat, with maize being the most frequently consumed and maple being the least consumed (Ali et al. 2017). During summer, Asiatic black bear in DHR were found to consume nine plant species, comprising both hard and soft mast, while in autumn, only six plant species were recorded, with no hard mast (Panthi et al. 2019). During spring, the Asiatic black bear primarily ate protein-rich plant-based food with low fiber content, but as the fiber content in their diet increased ort the protein content decreased, which typically occurred in late spring, the bears stopped feeding on tree leaves (Furusaka et al. 2017). Asiatic black bears diets change seasonally during spring, they mainly consume graminoids and forbs, shifting towards soft fruits in summer, and transitioning to a higher proportion of hard nuts and acorns as fall approaches (Huygens et al. 2003).

2.3. Species Distribution Modeling

Species Distribution Modeling (SDM) is a method used to identify the possible geographical range of a species (Pearson et al. 2007), by analyzing the environmental factors found in locations where the species is known to live (Phillips et al. 2006). MaxEnt is a flexible method that is used to make predictions or reach conclusions based on limited information. It has been noticed to perform better than other models in terms of its effectiveness (Elith et al. 2011). MaxEnt is a flexible method that is used to predict or make inferences based on incomplete data. It has been found to perform better than other models, particularly when dealing with species that have limited data samples and are restricted to specific geographic areas (Elith et al. 2006). The jackknife method, commonly referred to as the 'leave-one-out' approach, evaluate the model's performance by examining its capability to predict the location that was omitted from the training dataset (Pearson et al. 2007). MaxEnt was employed to assess the potential suitable habitat for a vulnerable tree species with limited data availability, resulting in a low omission rate and statistically significant outcomes (Kumar & Stohlgren, 2009).

3. MATERIALS AND METHODS

3.1. Study area

Dhorpatan Hunting Reserve (28°33′20″–28°48′00″N and82°51′00″–83°12′00″E) was established in 1983 and was gazetted in 1987. It comprises 1325 $km^{2,}$ and is situated in the lap of Dhaulagiri Mountain range of western Nepal. The primary goals of the reserve are to allow trophy hunting and protect a typical high-altitude ecosystem in western Nepal (Kandel et al. 2022). It lies in three districts; East Rukum, Myagdi and Baglung. The protected area is attributed to temperate, sub-alpine, and alpine vegetation and has an altitude range of 2700 m to above 7000 m. Most of the area above 4000 m of the reserve has highland meadows locally known as Patan.

Flora of DHR includes East Himalayan Fir (*Abies spectabilis*), Blue pine *(Pinus wallichina*), Birch *(Betula utili*s), Azalea (*Rhododendron spp*.), Hemlock (*Tsuga domusa)*, Oak (*Quercussemi carpifolia*), Black juniper (*Juniperus indica*), Spruce (*Picea smithiana*), Maple (*Acer caesium*), Juglans (*Juglans regia*), Taxus (*Taxus bacata*), and Chirpine (*P. roxburghii*) (Aryal et al. 2010).

The reserve is home to more than 18 species of mammalian fauna including species like Himalayan black bear *(Ursus thibetanus)*, Red panda (*Ailurus fulgens*), Leopard (*Panthera pardus*), Blue sheep (*Pseeudois nayaur*), Himalayan goral (*Naemorhedus goral*), Himalayan serow (*Capricornis thar*) and Leopard cat (*Prionailurus bengalensis*) (Regmi et al. 2023). Additionally, the DHR is home to several endangered mammal species, such as the Wolf (*Canis lupus*), Snow leopard (*P. uncia*), and Bharal or Nayaur (*Psueudois nayaur*) (DHR, 2019). The DHR has documented a total of 149 bird species, with pheasants and partridge being commonly found. Among them, notable species includes Blood pheasant (*Ithaginis cruentus*), Cinereous vulture (*Ageypius monachus*), Himalayan griffon (*Gyps himalayensis*) and globally threatened Cheer pheasant (*Caterus wallichi*) (Panthi & Thagunna, 2013).

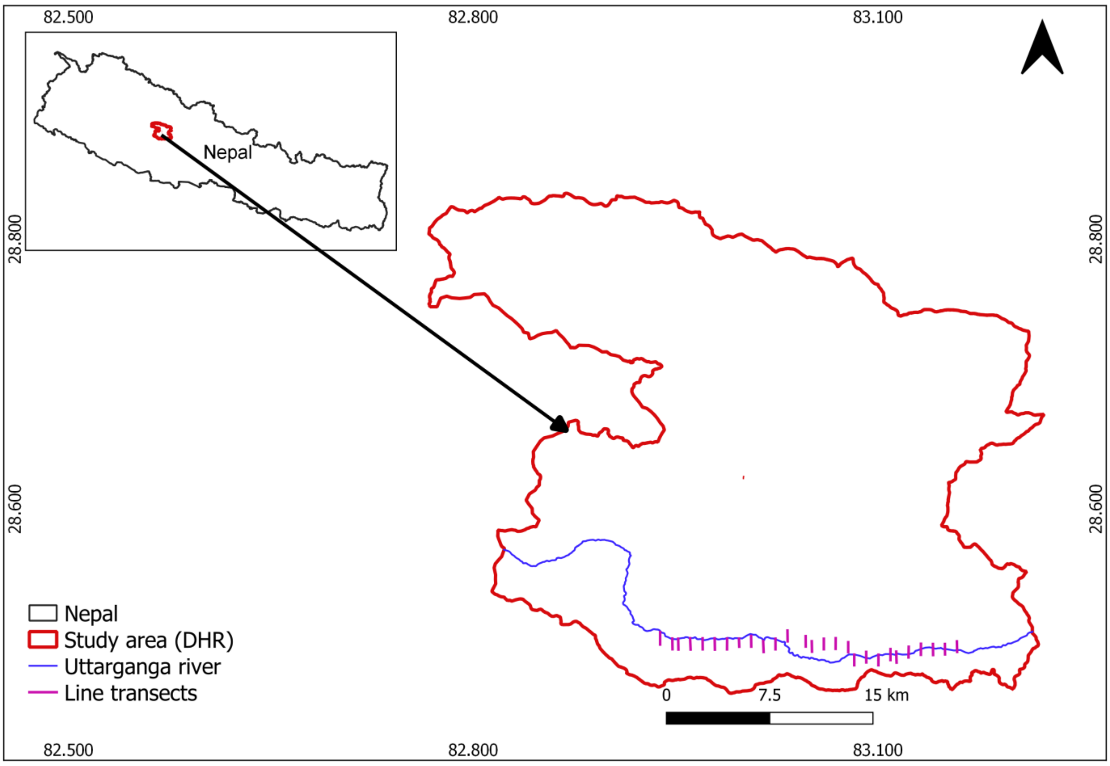

Figure 1 : Dhorpatan Hunting Reserve with established line transects for the study

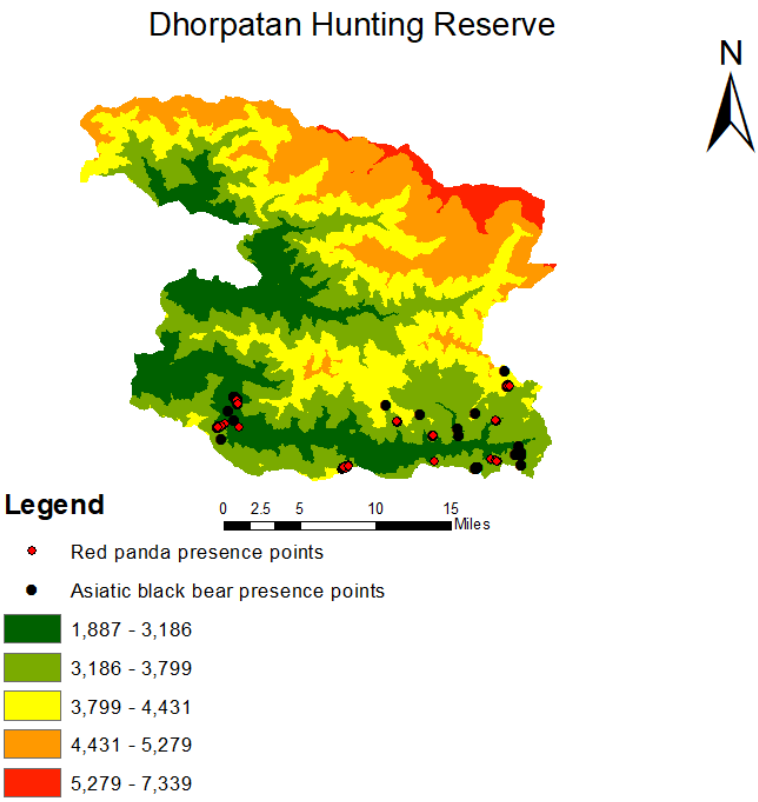

Figure 2 : Displays the presence points of both species in the study area, along with an overlay of elevation data.

3.2. Data collection

3.2.1. Distribution of Asiatic black bear and Red panda

The presence locations of Asiatic black bear and Red pandas were collected from DHR. The occurrence locations were recorded from established 37 line transects and opportunistic observations. A 1 km line transect was established in three blocks (Barse, Phagune, and Surtibang) of DHR and the interval between two transects was 1000 m in each block. The line transects were set up along the foot trails and the river the Uttarganga River (Figure 1). A 10×10 m study plot was established along the line transect at the interval of 250 m. A total of 148 study plots were developed for data collection, and the study was carried out from 8 September to 7 November 2022.When the distance to the closest Human settlement was less than 200 m, we employed a measuring tape for measurement; while distances more than 200 m were assessed using Google Earth. The Gap Light Analysis Mobile Application (GLAMA; Tichý, 2016) was used to document the forest Canopy cover. In each plot the presence location of Asiatic black bear and Red panda were recorded. In addition, the opportunistic presence locations of both species were also recorded from the foot trails when the species sign were found in new places or after personal communication to the local people. The presence location of each species which were >1 km was used for modeling.

3.2.2. Variable selection

First of all, add a Shapefile of Nepal containing roads, buildings, water bodies, and settlements. Convert this Shapefile into a raster format using the following settings in QGIS: Use the roads, buildings, and Water body fields, selecting the area with the code "123". Set the output raster size units to pixels and save it in a temporary file. Next, define the output extent by selecting the extent of the layer representing Nepal in the Shapefile. Assign a specified "no data" value of -999 to the output bands. Then, use the processing toolbox to run the "Inter Proximity Raster" tool without making any changes except for enabling the "distance only" option. Afterwards, perform a raster extraction by clipping the raster using a mask layer. Select the distance as the input layer and the Nepal Shapefile as the mask layer. Ensure that both layers have the same Cordinate Reference System (CRS) and assign a specified "no data" value of -999. Preserve the resolution of the input layer raster and run the tool. Next, perform another raster extraction by clipping the raster based on the extent. Use the clipped mask and the clipping extent, which should be set to the layer extent of the DHR and the temporary file, respectively. Set the CRS of the input layer raster to EPSG:4326 and select the DHR Shapefile as the mask layer. Also, make sure to preserve the resolution of the input raster and exclude the value -999. Run the tool. Finally, convert the clipped (masked) raster to another format by using the "Translate" function. Set the input as the clipped mask and choose the appropriate CRS. Make sure to leave the "no data" value unset (-999). Save the output file in ASC file format.

Using both Variance Inflation Factor (VIF) and correlation analysis helps ensure that the selected variables in a regression analysis are not highly correlated or collinear, which is important for obtaining accurate and reliable results. Correlation analysis is to consider using scatter plots or heatmaps to visually explore the relationships between variables and identify potential patterns or trends. After the environmental layers, Topographic and Climatic were prepared, the variables were chosen based on the VIF (Table 1) and correlation analyses. Only variables that did not show high correlation or collinearity were selected. To assess collinearity, the collinearity test was conducted using the R program (R Core Team, 2022). Finally, four bioclimatic variables (BIO_02, BIO_09, BIO_14, BIO_15) and Settlement, Water body, Aspect, Slope, Roads, and Forest were used to model the distribution of Asiatic black bear and Red panda in DHR in Nepal.

3.2.3. Data analysis

The information, which consisted of recorded and estimated data, was arranged and entered into an Excel spreadsheet to make analysis easier. Then, R-studio was used to analyze the data. The study aimed to understand where the Asiatic black bear and Red panda preferred to live, so Generalized Linear Modeling (GLM) was used for this analysis. Before conducting GLM, the research aimed to identify the environmental factors that had a statistically significant relationship with the population and distribution of Asiatic black bears and Red pandas. This was done by selecting variables that showed the lowest AIC value. A correlation test was performed to determine which predictor variables were highly correlated (above -0.8 and below +0.8). Finally, the best-fitting model in GLM, which explained the habitat preferences of Asiatic black bears and Red pandas in their natural habitat, was selected. In the study, the researchers looked at the number of signs of Asiatic black bears and the number of scats from Red pandas as the things they were trying to understand. They also considered various topographic and environmental factors as the things that might help explain these numbers. They used a statistical method called GLM with a Poisson distribution because the data they collected was in discrete form. They tried out different combinations of variables in the GLM to see which models fit the data best. The model with the lowest AIC value and looked at the marginal and conditional R-squared values to understand the habitat preferences of Asiatic black bears and Red pandas. The GLM analysis includes environmental variables such as Distance from Roads, Distance from Water body, Distance from Human settlements, Ground cover, and Canopy cover. Topographic variables, including Aspect, Elevation, and Slope, are also utilized. The selection of these variables is based on their significance, while other variables are excluded from the analysis. They used the Coefplot2 and Sjplot packages to estimate standardized coefficients and marginal and conditional values, respectively. In addition, ggplot in R program (R Core Team, 2022) to create boxplot graphs for the variables (Distance from Human settlement, Ground cover, and Aspect) that showed statistical significance. These graphs were used to demonstrate the influence of these variables on Asiatic black bears and Red pandas.

Table 1 : VIFcor between predictive variables used in model.

Variables ID	**Variables Name**	**VIFcor Values**
BIO_02	Mean Diurnal Range (Mean of Monthly (max temp - min temp)	1.514
BIO_09	Mean Temperature of Driest Quarter	2.433
BIO_14	Precipitation of Driest Month	2.912
BIO_15	Precipitation Seasonality (Coefficient of Variation)	2.800
Settlement	Distance to nearest Human settlement	1.950
Water body	Distance to nearest Water body	1.457
Aspect	Aspect	1.041
Slope	Slope	1.058
Roads	Distance to nearest Roads	1.345
Forest	Distance to nearest Forest	2.335

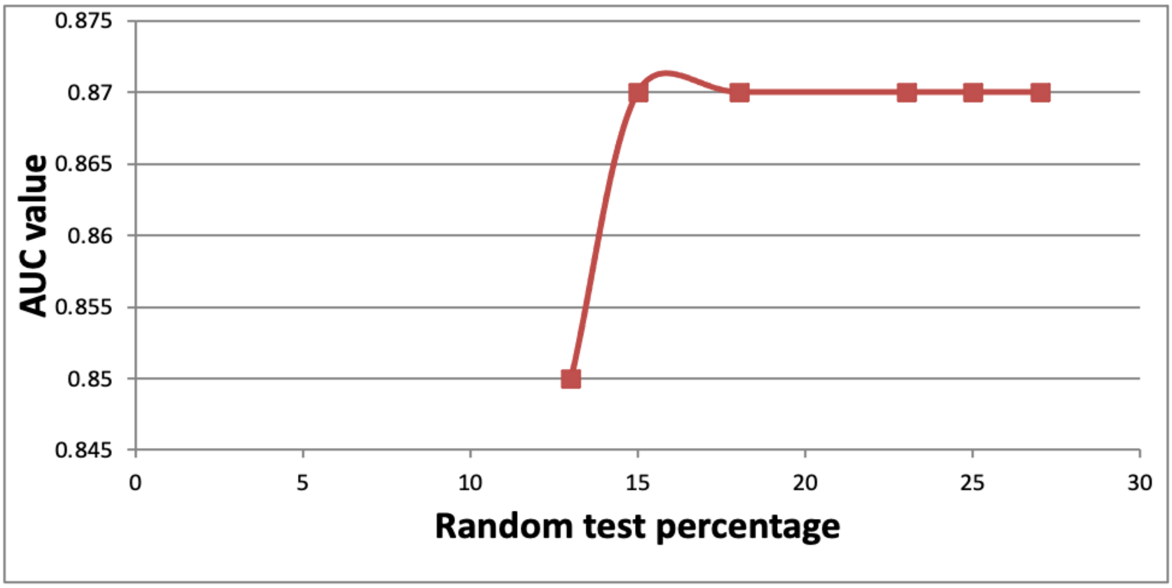

Figure 3 : Random test percentage with Area under the Curve Receiver Operating Characteristics

The presence data was divided into subsets of 75% and 25% as training and test data sets. These subsets of data were selected for MaxEnt based on the Area Under the Receiver Operating Characteristics (AUC) value obtained from many random test percentages (Figure 2).

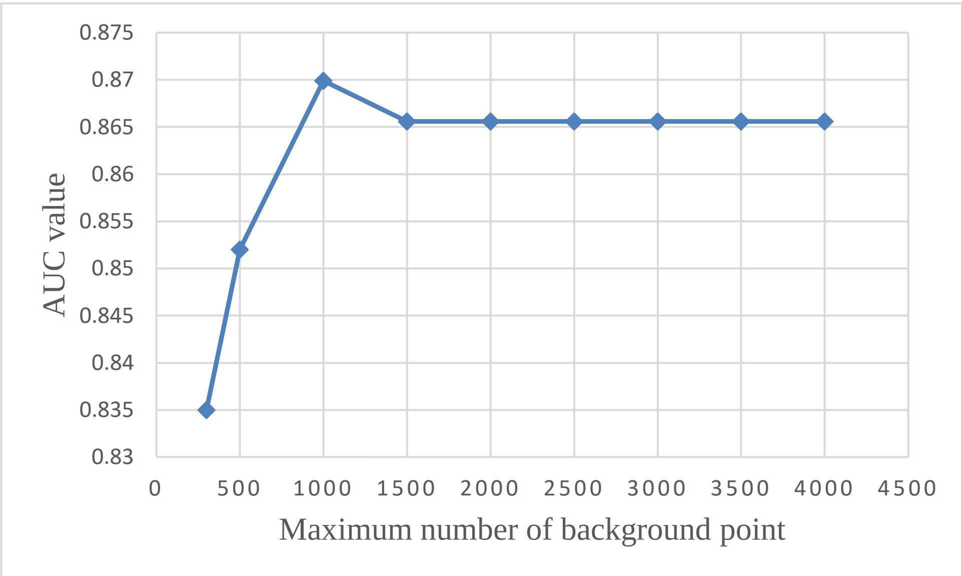

Figure 4 : Number of background points with Area under the Curve Receiver Operating Characteristics

A 2000 background point was used for a model based on the constant AUC value obtained at different background points (Figure 3). MaxEnt determines the available environments by sampling a large number of background points distributed across the study area. Background points use the available environment for predicting the suitable habitat. If the number of background points is larger, then this number of cells is chosen randomly for background points, and these are also acts as pseudo absence data (Phillips et al. 2009).

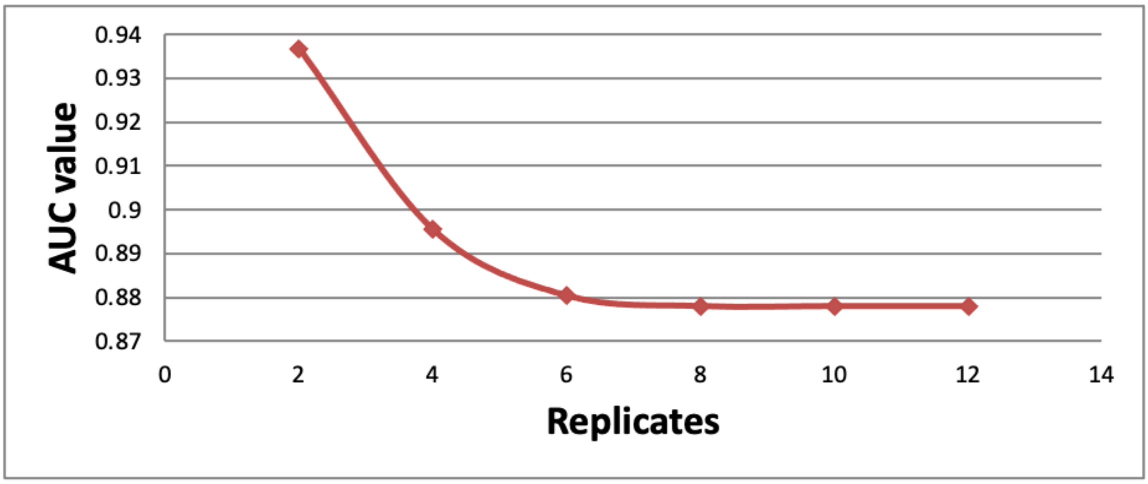

Figure 5 : Replicates number with Area under the Curve Receiver Operating Characteristics

During the model construction, a constant AUC values was obtained from seven replicates to 12 replicates (Figure 4), therefore, the final models were run at 10 replicates. In both Figure 4 and 5, when a constant value starts to remain the same, the next value is used consistently to maintain continuity.

3.2.5. Asiatic black bear and Red panda distribution modeling

Two models were used in the study, one relied only on bioclimatic variables, such as BIO_02, BIO_03, BIO_14 and BIO_15, while the other model included additional variables such as Settlement, Water body, Aspect, Slope, Roads, and Forest, as well as the bioclimatic variables BIO_02, BIO_03, BIO_14 and BIO_15. The occurrence data were divided into two subsets, with 75% used for training and 25% used for testing, for both models. Linear and quadratic features were applied to the models (Elith et al. 2011), with 2000 background points, and default settings were used for other features. Additionally, bootstrapping was used due to the small sample size, and 10 replicates were constructed for each model (Figure 4).

The model performance was evaluated based on the AUC value (Allouche et al. 2006). The model performance was investigated using an extrinsic omission rate. The omission rate is a fraction of test localities that fall into pixels not predicted as suitable for Asiatic black bear. By calculating AUC, the prediction accuracy and validation of the models can be assessed (Yang et al. 2013). The Area Under the Curve is a statistical measure that calculates the likelihood of a random presence site being ranked higher than a random absence site. This measure is not dependent on a specific threshold and is used to evaluate how well a model distinguishes between the presence and absence (or background) of species. AUC scores range from 0.5 to 0.1, with 0.5 indicating that the model predictions are no better than random, scores less than 0.5 indicating worse than random performance, scores between 0.5 and 0.7 indicating poor performance, scores between 0.7 and 0.9 indicating moderate reasonable performance, and scores greater than 0.9 indicating high model performance (Fielding & Bell, 1997).

To create a suitability map for the species, a logistic threshold based on the maximum training presence was used, and evaluated the significance of each predictor using the jackknife method. To investigate changes in the distribution range of the species, change detection maps were created using various functions in QGIS. MaxEnt image suitability map of the species was created with values ranging from 0 (completely unsuitable) to 1 suitable. MaxEnt output was converted to suitable and unsuitable habitat using the Maximum Training Presence Logistic Threshold (Liu et al. 2016), and finally calculated the potential area.

3.2.6. Environmental variables

Nineteen bioclimatic variables were downloaded at 30 arc second (*ca*. 1 km^2) (Fick & Hijmans, 2017) worldclim (https://worldclim.org/) and Roads, Water body and Settlement data was used downloaded by (https://download.geofabrik.de/asia/nepal.html). The raster layer of the Roads, Water body and Settlement was developed with Euclidian distance and upscale the raster layer to 30 arc second (*ca*. 1 km^2) resolution based on the mean values of raster cells. The downloaded environmental layers were cropped with a DHR mask layer. The 30 arc second digital elevation model (DEM) from the Japan Aerospace Exploration Agency's (JAXA) (https://www.eorc.jaxa.jp/ALOS/en/aw3d30/registration.htm)was used to calculate Slope and Aspect. Topographic and vegetation related variables, anthropogenic variables are equally important to identify how human activities affect the distribution of wilds animals. Tree Canopy cover was defined as the canopy closure for all vegetation taller than 5 m in height. These all-environmental variables are present raster form they are converting into ASCII Grid file from QGIS than they are used in MaxEnt for identified habitat suitability (Phillips et al. 2006).

4. RESULTS

4.1 Spatial locations of Asiatic black bear and Red panda

A total of 57 presence locations (30 from Transects and 27 opportunistic) of Asiatic black bear and 72 presence locations (32 from 40 Transect and 32 opportunistic) of Red panda were collected during this study. The occurrences of these species were recorded from the elevation range of 2657 m to 4016 m within the DHR. The recorded plots were located approximately at the average of 211.49 ± 133.19 m close to the nearest Water body. The average Ground cover in the study plots was 48.37 ± 22.84%, and the average Slope was 28.84˚± 11.36˚. Furthermore, the average elevation of the study plots was 3270.71 ± 275.84 m. The study plots were at the average distance of 2533.77 ± 965.28 m from Human settlements, and the average Canopy cover of the study plots was 59.48 ± 23.53%.

4.2. Model performance

Two models for Asiatic black bear and Red panda distribution in DHR were constructed: 1) models only with climatic variables and 2) model with climatic variables, and Road, Settlement, Water body, Slope, Aspect and Forest, which were developed with presence-only data and predictive variables.

Table 2: Asiatic black bear and Red panda model performance based on the Area Under the Curve Receiver Operating Characteristics (AUC)

Model on Asiatic black bear	**Training AUC value**	**Test AUC value**
Climatic models	0.8844	0.8245
Model with climatic and other variables	0.8861	0.8589
Model on Red panda	**Training AUC value**	**Test AUC value**
Climatic models	0.8962	0.8997
Model with climatic and other variables	0.9016	0.7947

A B

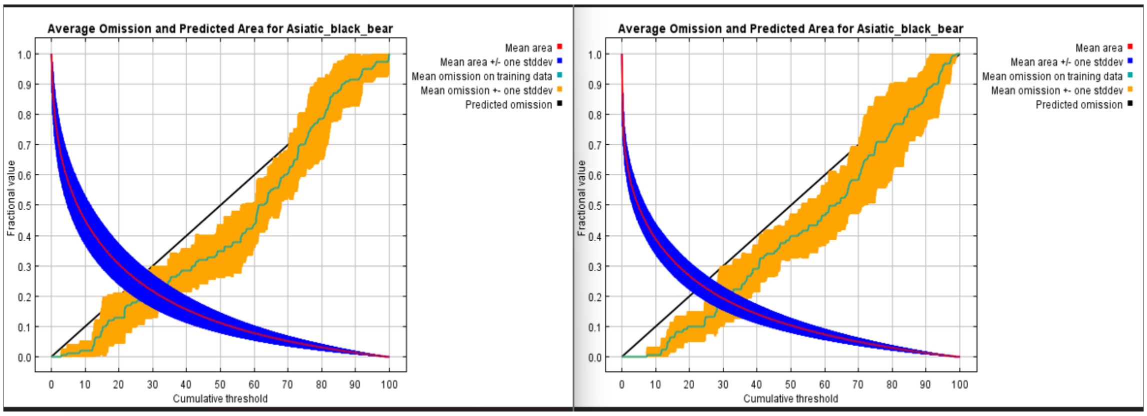

Figure 6 : Testing and training omission and predicted area for Asiatic black bear and (A) model only with climatic variables and (B) model with climatic and Forest, Road, Settlement, Slope, Aspect, and Water body.

Both models performed well with higher AUC values (Table 2). The correlation between the testing and training omission rates, along with the predicted area under various threshold values, demonstrates a strong relationship in both cases for the Asiatic black bear both only climatic variables, climatic and other variables (Figure 6A & B). Additionally, the predictions exhibit a small standard deviation, indicating the reliability of the model's performance. The figure indicated how the testing and training omission and predicted area varies with the choice of cumulative threshold.

A B

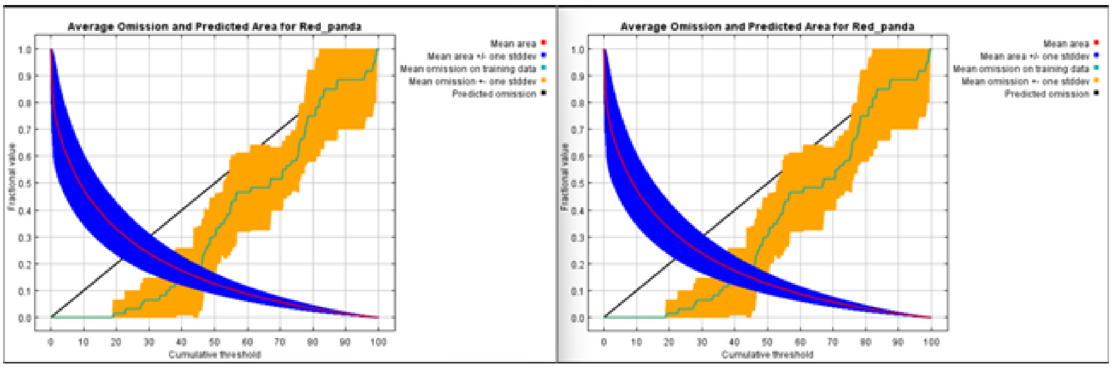

Figure 7 : Testing and training omission and predicted area for Red panda and (A) model only with climatic variables and (B) model with climatic variables, Forest, Road, Settlement, Slope, Aspect and Water body.

In case of Red Panda also both the model performed well with higher AUC values. The correlation between the testing and training omission rates, along with the predicted area under various threshold values, demonstrates a strong relationship in both only climatic variables and climatic and other variables (Figure 7A & 6B). Additionally, the predictions exhibit a small standard deviation, indicating the reliability of the model's performance.

A B

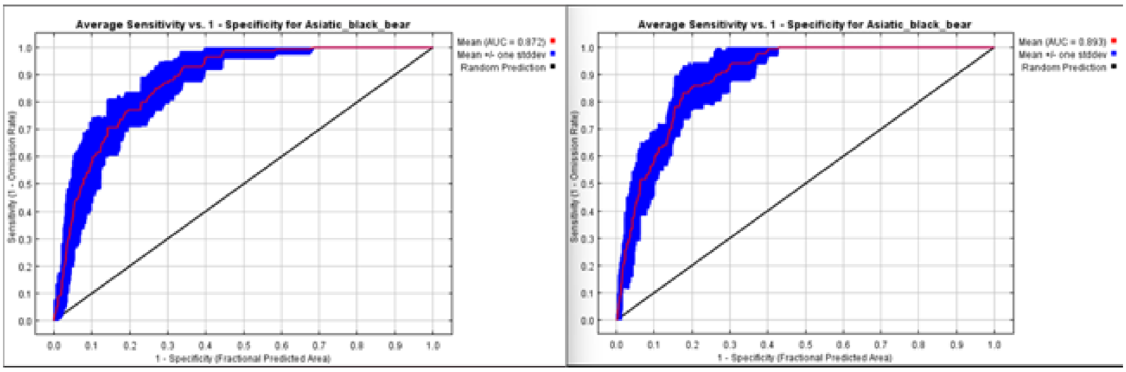

Figure 8 : Area under the Curve Receiver Operating Characteristics value for test and training data for Asiatic black bear; (A) model only with climatic variables and (B) model with climatic variable, Forest, Slope, Aspect, Road, Settlement, and Water body. The red line is the average value, and the blue bar represents plus and minus one standard deviation.

The assessment of smoothness and width of the standard deviation indicators is crucial in evaluating the accuracy and reliability of the model for predicting the distribution of Asiatic black bears. These indicators reveal the spatial consistency and precision of the predicted distribution capacity in only climatic variables and climatic and other variables (Figure 8A & B). Smoothness is a factor in assessing the gradual changes observed in the predicted distribution across the landscape. When the distribution appears smoother, it successfully captures the fundamental patterns and environmental factors influencing the species' distribution. The width of the standard deviation offers valuable insights into the variability and unpredictability linked to the predicted distribution. The performance of the model was poorer than a random model, and the values below the straight line were no better than random, and the model performance was worse than a random model.

A B

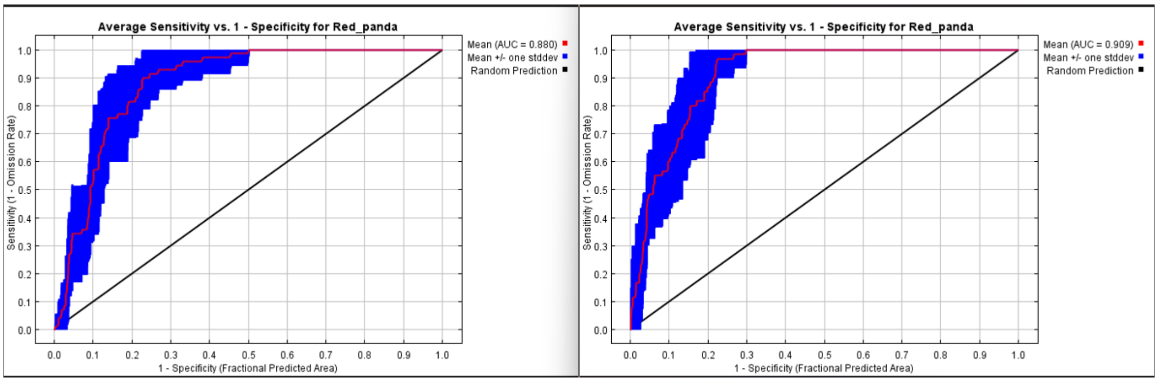

Figure 9 : Area under the Curve Receiver Operating Characteristics value for test and training data for Red panda and (A) model only with climatic variables and (B) model with climatic variable, Forest, Slope, Aspect, Road, Settlement and Water body. The red line is the average value, and the blue bar represents plus and minus one standard deviation.

The model's goodness-of-fit and predictive power for Red panda data can be assessed through the smoothness and width of the standard deviation. The evaluation of the model's performance at only climatic variables and both climatic and other variables provide a comprehensive analysis of their impact on the model's accuracy and predictive capabilities for the Red panda data (Figure 9A&B). The values below the black straight line were no better than random, and the model performance was worse than a random model.

A **B**

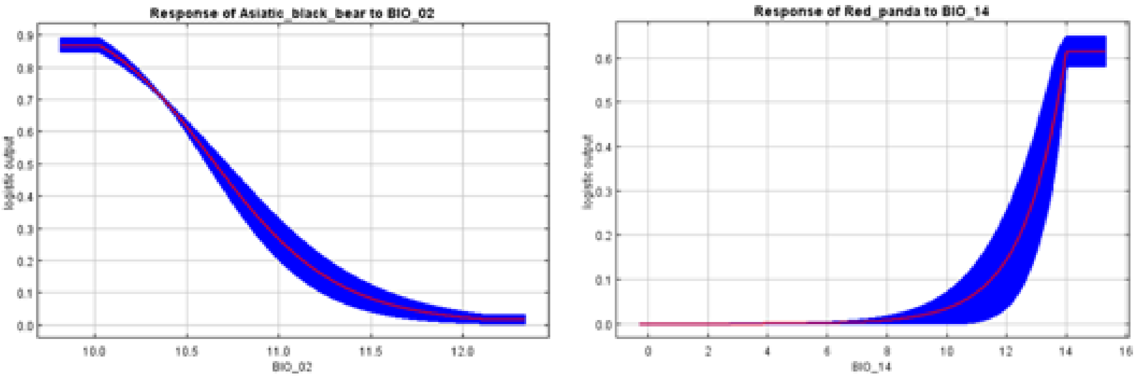

Figure 10 : Response curves of Asiatic black bear (A) (BIO_02 (Mean Diurnal Range)) and Red panda (B) (BIO_14 (Precipitation of Driest Month)) with only climatic variable

Responses of each environmental variable that influenced the predicted suitable distribution of Asiatic black bears are shown in response curves. These response curves showed changes in the probability of suitability when each environmental variables change by keeping all other environmental variables at their average sample value. Red pandas are strongly influenced by the Mean Diurnal Range (BIO_02) between 10.025°C and 12.125°C with only climatic variable. The habitat of Asiatic black bears are primarily controlled by the Precipitation of Driest, which represents the difference between the highest and lowest temperatures over a year. They prefer areas with a narrow temperature fluctuation and are well-adapted to environments where daily temperature variations are limited, typically ranging from 10.025°C to 12.125°C. Temperature conditions likely support the physiological processes, activity patterns, and survive of Asiatic black bears. On the other hand, Red pandas are strongly influenced by Precipitation of Driest Month (BIO_14). The variable "Precipitation of Driest Month" (BIO_14), which can range from 1 mm to 14 mm, represents the amount of precipitation in the driest month of the year. Red pandas have a wide tolerance for different levels of precipitation during this period. The range of 1 mm to 14 mm suggests that they can potentially occupy areas with very low levels of precipitation during the driest month.

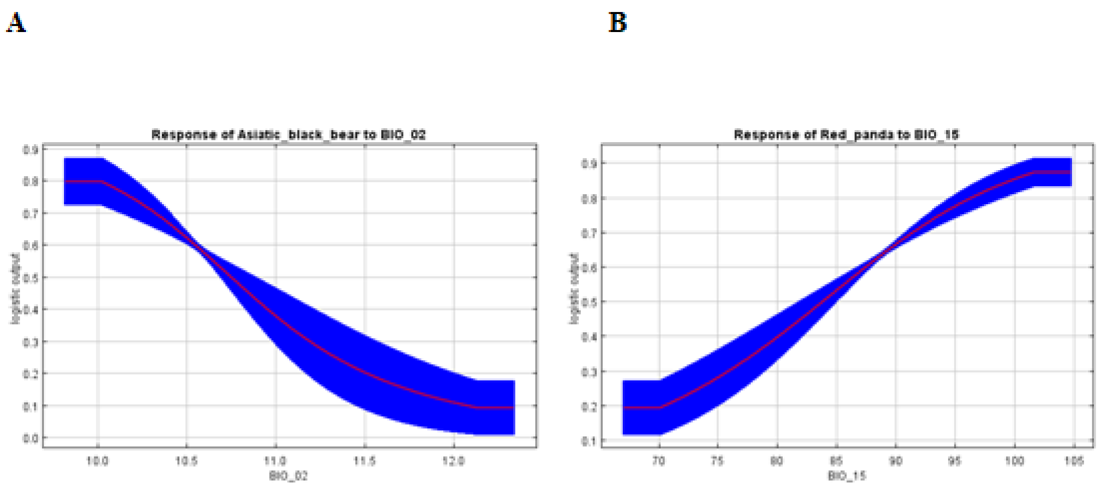

Figure 11 : Response curves of (A) Asiatic black bear (BIO_02 (Mean Diurnal Range)) and (B) Red panda (BIO_15 (Precipitation Seasonality (Coefficient of Variation)) with climatic and other variables.

Responses of each environmental variable that influenced the predicted suitable distribution of Red panda are shown in response curves. These response curves show changes in the probability of suitability when each environmental variables change by keeping all other environmental variables at their average sample value. The survival and well-being of Asiatic black bears are significantly affected by a climatic and other variable called Mean Diurnal Range (BIO_02), which spans from 10.025°C to 12.125°C. This variable represents the average temperature difference between the highest and lowest points over a year. The Asiatic black bears thrive in habitats that exhibit relatively small fluctuations in temperature throughout the day. The temperature range of 10.025°C to 12.125°C is considered optimal for the survival and overall health of Asiatic black bears. Through the use of climatic and other variables, models have revealed that the habitat of Red pandas is heavily influenced by BIO_15 Precipitation Seasonality (Coefficient of Variation). This variable, which ranges from 70.175 to 101.587 mm, measures the fluctuations in precipitation across the year, indicating the degree of seasonality in the Red panda's habitat. The observed range of values signifies notable variations in both the quantity and timing of precipitation, which can shape the habitat preferences and distribution patterns of Red pandas.

A **B**

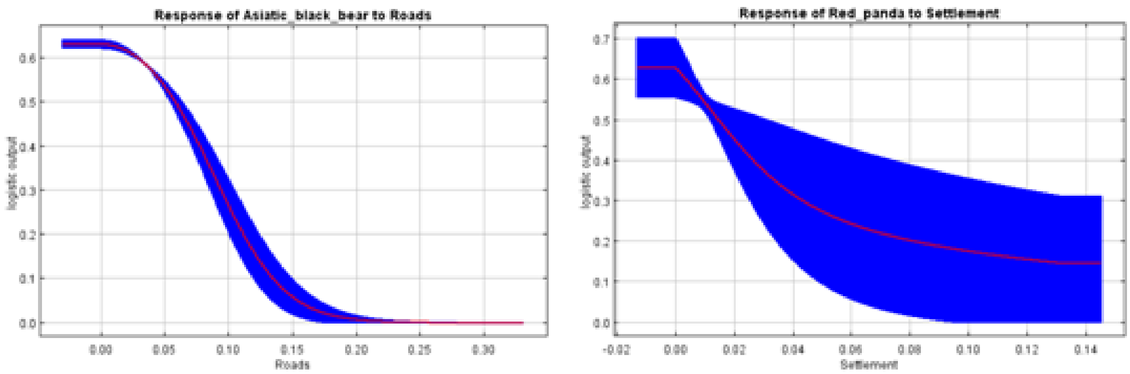

Figure 12 : Response curves of Asiatic black bear (A) and Red panda (B) with climatic and other variables. Roads (Distance to nearest Roads) and Settlements (Distance to nearest Settlements)

Both the Asiatic black bear and the Red panda were found to be closely associated with Roads and Settlements, in relation to both climatic and other variables. The presence of roads within approximately 301 meters had a negative impact on the occurrence of Asiatic black bears in DHR. The probability of finding Red pandas was higher near Settlements, and the areas within about 132 meters of settlements had a negative impact on the occurrence of Red pandas in DHR (Figure 12).

4.4. Predicted suitable habitat

MaxEnt was used to create habitat suitability maps for the Asiatic black bear and Red panda overlapping habitat. When considering only climatic variables, the suitable areas for Asiatic black bears were estimated to be 265 km^2. However, when incorporating both climatic and other variables, the suitable areas were slightly reduced to 256 km^2.The assessment based only on climatic variables indicated that the estimated suitable areas for Red pandas covered an area of 201 km^2. However, when additional variables were taken into account alongside the climatic factors, the suitable areas decreased to 178 km^2. Around 196 km^2 areas was overlapped for these two species in the DHR region was limited to under the climatic model, while 162 km^2 the suitable area was predicted under the climatic with anthropogenic variables included model in DHR (Table 3). The predicted distribution of the Red panda is significantly higher in areas with dense Canopy coverage, Ground cover, and abundant green vegetation.

Table 3: Suitable area predicted for Asiatic black bear and Red panda in Dhorpatan Hunting Reserve, Nepal

Species name	**Asiatic black bear**		**Red panda**	
	Suitable area (km^2)	**%**	**Suitable area(km^2)**	**%**
Only with climatic variable	265	18.45	201	13.99
Climatic, Environmental and Anthropogenic variable	256	18.56	178	12.90
	Overlapping area of Asiatic black bear and Red panda			
	Suitable area ($Km^{2)}$		**%**	
Only with climatic variable	196		13.64	
Climatic, Environmental and Anthropogenic variable	162		11.74	

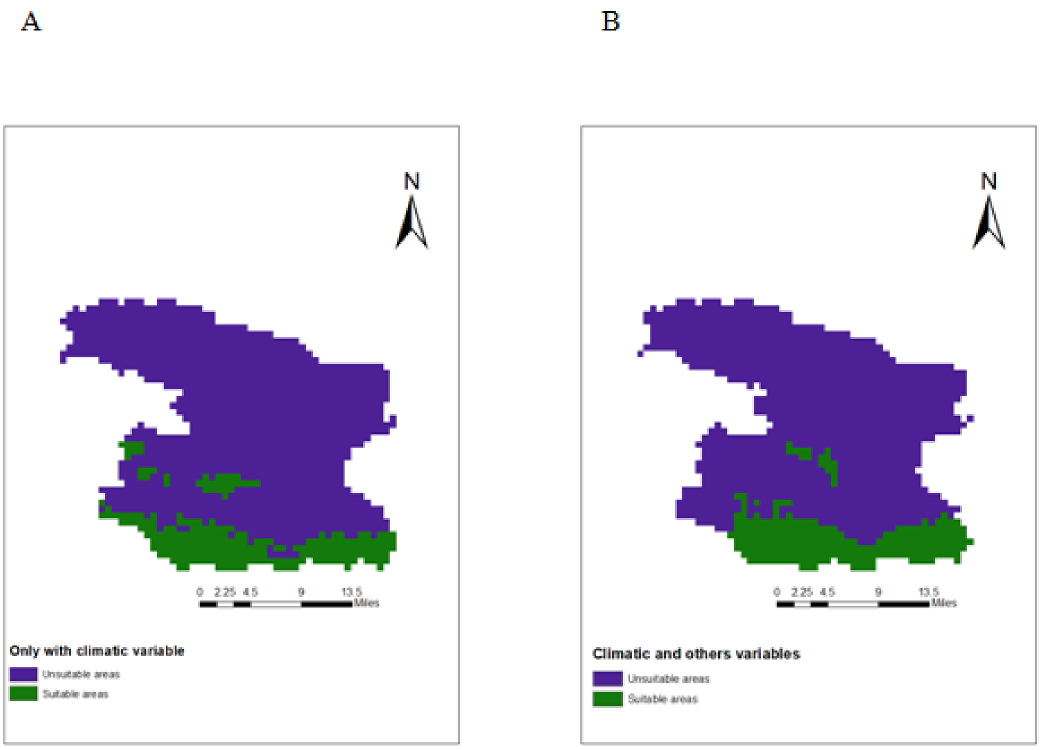

Figure 13 : Asiatic Black bear suitable habitat in DHR with only with climatic variable (A) and climatic with other variable (B)

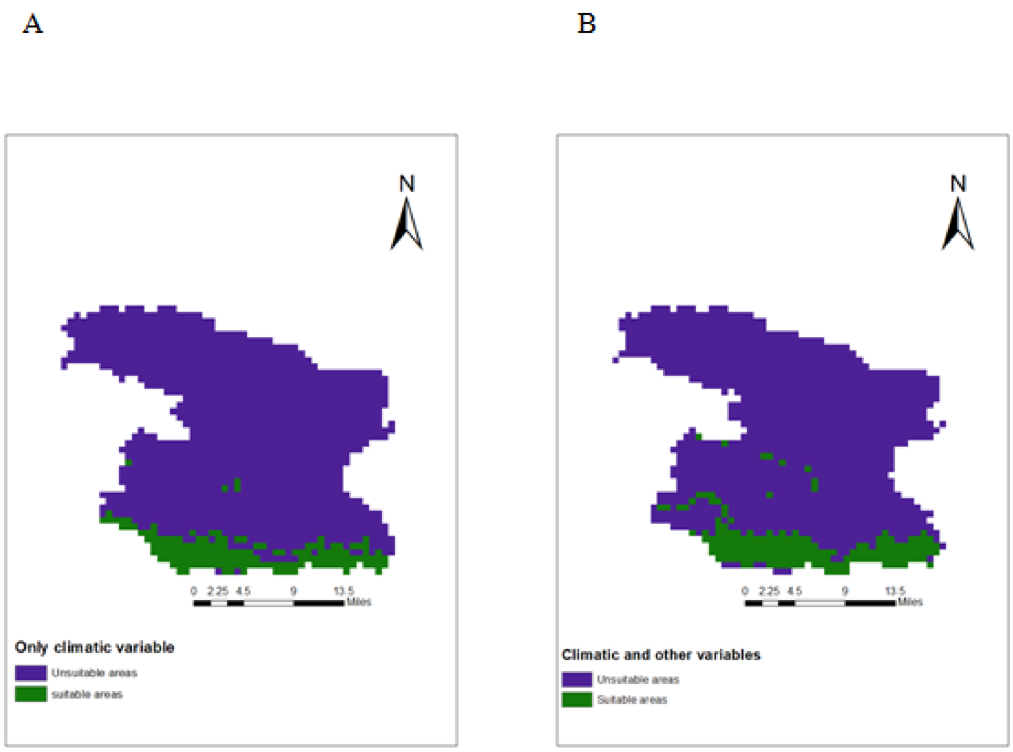

Figure 14 : Red panda suitable habitat in DHR with only with climatic variable (A) and climatic with other variable (B)

A   B

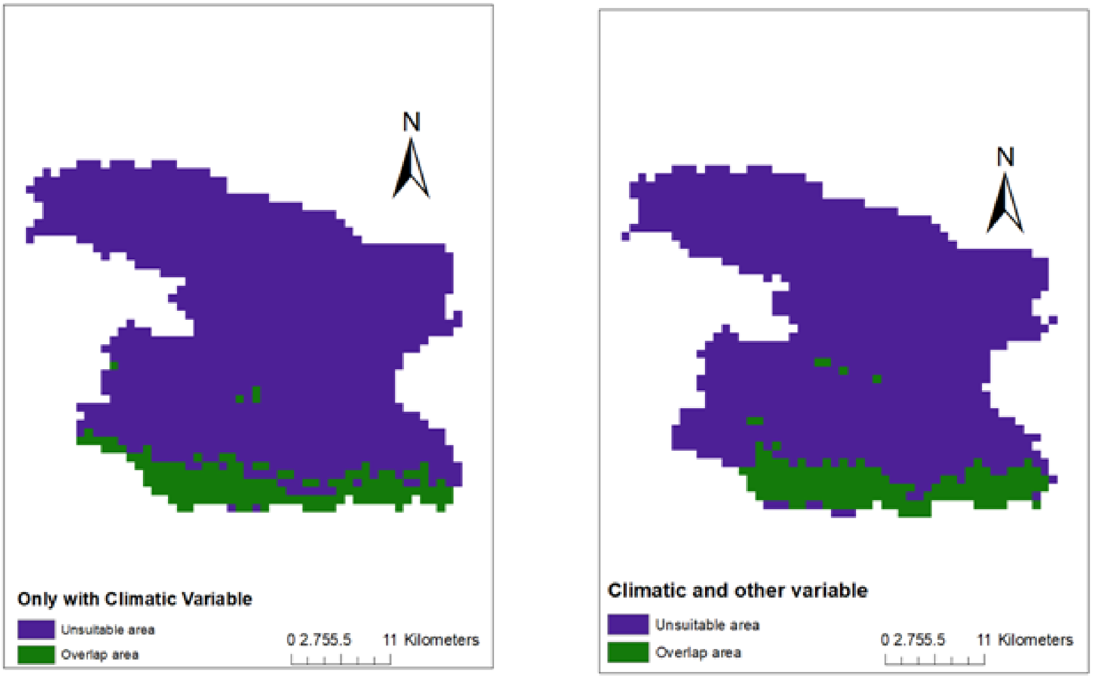

Figure 15 : Suitable habitat overlap between Asiatic Black bear and Red panda

Asiatic black bear

The study discusses p-values for different predictors (Slope, Distance from Water body, and Ground cover) and their significance. A p-value below 0.05 indicates a significant relationship between predictor and response, supporting a meaningful connection between the variables.

Table 4: Generalized linear modeling estimates and 95% confidence limits describing the Asiatic black bear occurrence in DHR, Nepal. Significant effects are Slope, Distance to a Water body and Ground cover.

Coefficients	**Estimate**	**Std. Error**	**z value**	**Pr(>|z|)**
(Intercept)	-1.4487	0.7505	-1.930	0.053
Slope	0.0251	0.0147	1.703	0.088
Distance to Water body	0.0021	0.0010	1.961	0.049
Ground cover	0.0284	0.0085	3.320	0.000

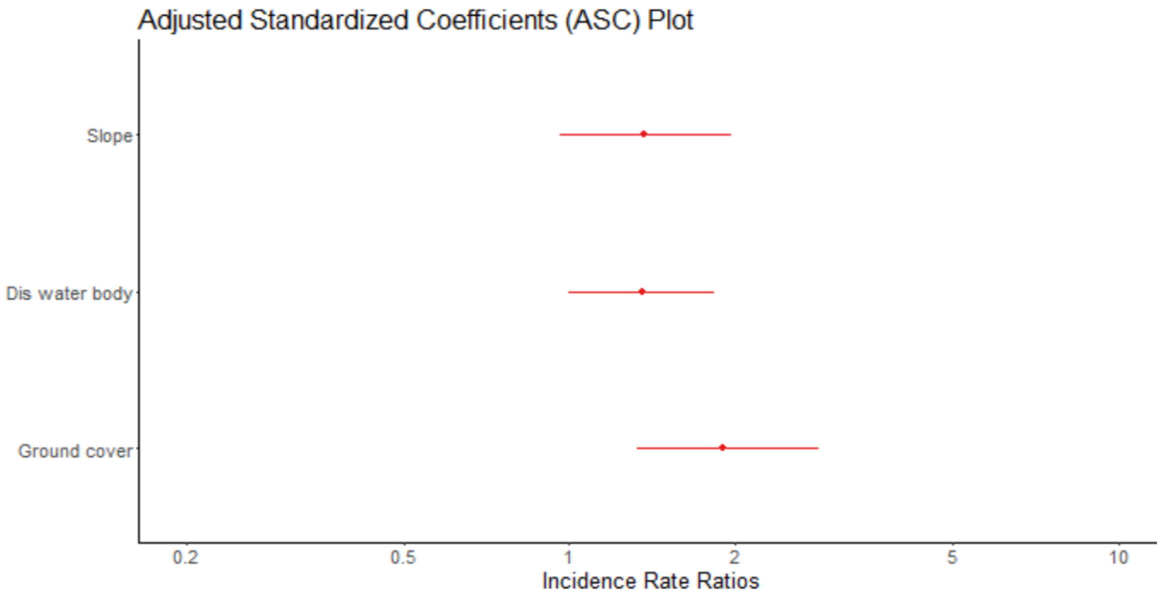

Figure 16: Adjusted Standardized coefficients (ASC) plot provides valuable information about the influence of different variables on the desired outcome of Asiatic black bear.

The study examines variables' impact on the incident rate ratio. Slope and Ground cover show significant positive associations, while distance from Water body has a weaker effect. These findings improve our understanding of the factors influencing the studied incidents.

Red panda

The coefficients in the table give us important information about how the predictors are related to the outcome. The starting point for the outcome is strongly influenced by the intercept coefficient. The Distance from Human settlement has a positive impact on the outcome. The Slope has potential positive impact but is not very significant. However, the Distance from Water body and Ground cover have significant negative impacts on the outcome. Overall, these coefficients give us valuable insights into how the predictors can influence the outcome.

Table 5: Generalized linear modeling estimates and 95% confidence limits describing the Asiatic black bear occurrence in DHR, Nepal. Significant effects are Slope, Distance to a Water body and Distance to Human settlement.

Coefficients	**Estimate**	**Std. Error**	**z value**	**Pr(>|z|)**
(Intercept)	1.6368	0.5288	3.095	0.001
Distance to Human settlement	0.0002	0.0001	2.140	0.032
Slope	0.0225	0.0129	1.744	0.081
Distance to Water body	-0.0027	0.0009	-2.794	0.005
Ground cover	-0.0250	0.0059	-4.184	2.87e-05

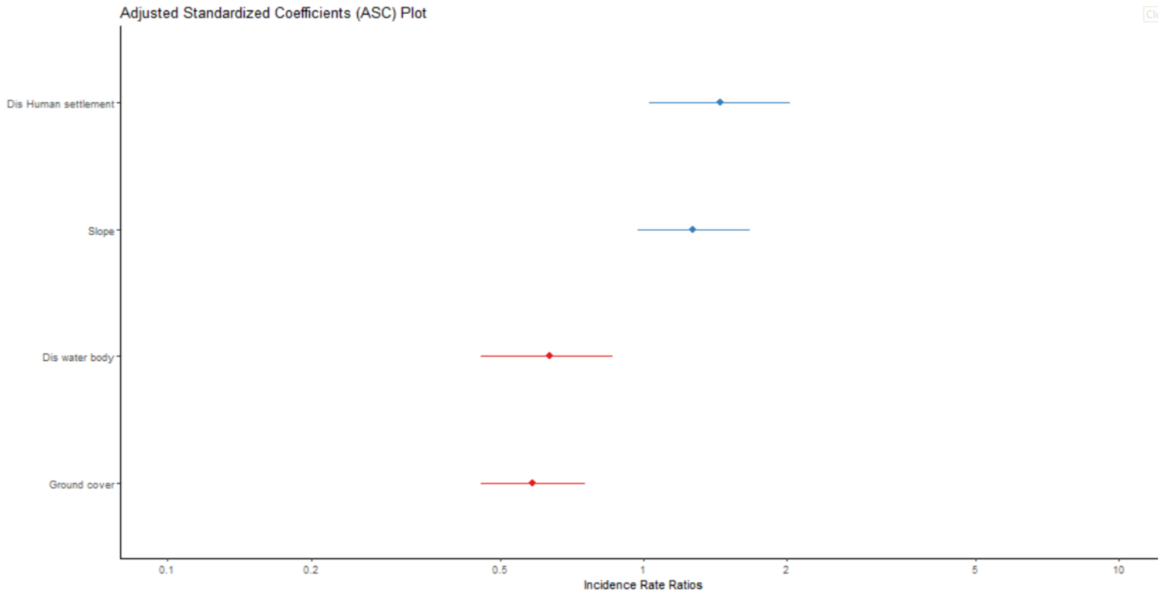

Figure 17: ASC plot representing the standardized coefficient of predictor variables in relation to a response variable of Red panda.

The Adjusted Standardized coefficients (ASC) plot shows that Distance from Water body and Ground cover values range from 0.5 to below 1, strongly impacting the outcome. Higher Ground cover and Aspect values increase the likelihood of the desired outcome. The Slope and Distance from Human settlement values range from 1 to below 2 on the incidence rate ratios scale, indicating a moderate positive effect on the outcomes. Higher values of these variables increase the likelihood of the desired outcome.

5. DISCUSSION

The model performance for both the climatic variable only and the model incorporating climatic and other variables was good. The goodness-of-fit for both models were assessed using the Area Under the Curve (AUC), and they displayed high AUC values close to 1. These near perfect AUC values indicate a high level of predictive performance and are expressive of the models' superior accuracy in forecast the outcomes. The both models show that the range expansions of Asiatic black bear and Red panda will be increasing rapidly, invading towards South and expanding to South direction, and the species can spread to low-mountain areas due to high canopy forest and bamboos. The Asiatic black bear was mostly found in dense forest and edge of the agricultural land with forest (Bista & Aryal, 2013).

In our study Human settlement are strongly influence the Asiatic black bear habitat in DHR also (Regmi et al. 2023) Human settlements are much farther away, and particularly in the case of Asiatic black bears, their presence has been growing in the DHR. The Ground cover plays a crucial role in determining the suitability of the Red panda's habitat in the Dhorpatan Hunting Reserve (DHR). It was observed that the presence of livestock had a significant positive impact on the Red pandas, possibly because they share bamboo as a food source (Sharma et al. 2014). The Red panda shows a preference for habitats that have thick Canopy coverage and Ground cover (Bhatta et al. 2014). The study findings indicated that both the habitat of Asiatic black bears and Red pandas are influenced by many factors, Distance to Human settlement, Distance to Water body, Ground cover, a low amount of rainfall during the driest month and a limited range of temperature fluctuations. Panthi et al. (2019) have shown that the suitable habitat for the Red panda is significantly influenced by factors such as forest cover, distance to roads, as well as temperature and precipitation. Red pandas tend to exhibit increased activity in areas with high vegetation and dense Canopy cover in DHR (Sharma & Belant 2010). The suitability of the Red panda's habitat was identified using Species Distribution Modeling (SDM), with the key climatic factors influencing it being temperature and precipitation (Thapa et al. 2018). Study of two models predicted a common habitat for both species in the southern region and the densely forested areas of DHR that covers a major portion of the forest area. Dense forest cover was a major potential habitat for both the Asiatic black bear and the Red panda. Similarly, these areas were suitable for species probably due to available for both bamboo and other fruiting specie (Bhatta et al. 2014b, Garshelis &

Steinmetz, 2016**).** Due to available of these feeding resources both species prefer the same habitat. The study temperature fluctuations in narrow habitats are suitable for both Asiatic black bear and Red panda. Climate is a fundamental factor that holds significant importance in shaping the distribution patterns of various species. The complex interplay between climate and species' distribution is influenced by various environmental variables like temperature, precipitation, humidity and altitude (Morelle & Lejeune, 2015).

The potential habitats of Asiatic black bears are suitable more compared to those for Red pandas. The models considering only climatic variables and both climatic and anthropogenic variables revealed that there is overlap in a greater proportion of suitable habitats between these species. The climatic model for both species predicted more suitable habitat than models with climatic and other variables. Generally, climatic variables predict suitable habitat for providing the fundamental niche while another model provides realized niche (Odum et al. 1998). In addition, the wider potential distribution for Asiatic black will be beneficial due to their wider distribution than Red panda (Jnawali et al. 2011). Not only in DHR, the estimated potential distribution area of Asiatic black bear larger than Red panda in MBNP (Su et al. 2021b). Endemic habitats of mammals are facing significant losses as a result of human activities, highlighting the harmful impact of anthropogenic factors on the natural environments in which these species reside in DHR (Regmi et al. 2023). Red pandas are vulnerable to the loss of bamboo due to direct human activities (Sharma et al. 2014a).

The suitable areas for the Asiatic black bear and the Red panda, as well as the areas where they overlap, are not significantly different. This indicates that these two species are sympatric mammals, meaning they coexist in the same habitat with similar characteristics. They both occupy temperate forest and rely on similar food sources for their survival (Chhetri et al. 2013; Glatston et al. 2015). Red pandas display a specialization in their habitat selection, favoring forested areas abundant in bamboo. The Asiatic black bear alters its diet throughout the seasons, consuming succulent plants in spring, insects from fruit-bearing trees and shrubs in summer, transitioning to nuts in autumn, and engaging in carcass scavenging (Huygens et al. 2003).

Based on the data in, the overlap between Asiatic black bear and Red panda habitats was 13.64% when considering only the climatic variables model, while it was 11.74% when both climatic and anthropogenic variables were taken into account. The bamboo played a crucial role as the primary food source for Asiatic black bears in DHR during both summer and autumn, comprising approximately one-third to one-fifth of their total diet, highlighting its significance in the Asiatic black bears' food habits in Nepal (Panthi et al. 2018).

The presence Red pandas within an altitude range of 2670 m to 3678 m observed in this study is similar to the finding of (Yonzon & Hunter, 1991). The presence of Red pandas within an altitude range of 2876 m to 3806 m observed in ACA (Bista et al. 2017). Red panda was present on 3000 m to 3600 m elevation in DHR (Sharma & Belant, 2009). The study Red panda signs sighting were recorded in distances from water resources were observed within a distance of 10 m to 480 m from water sources. (Bista et al. 2017) conducted research found the presence of water sources within 0 to 100 m was a crucial habitat requirement for Red pandas, as indicated by higher frequency of Red panda dropping in those areas. The study found that the distribution of Asiatic black bears and Red pandas is significantly influenced by the arrangement of vegetation, particularly in areas with abundant low lying bamboo plants. These species were found in moderate numbers in locations with slopes averaging between 30° to 48.86° in the DHR. The current study was almost as large as the previous one. Asiatic black bear and Red panda sings were recorded within the Slope range of 28.84° ± 11.36°. The Asiatic Black bear was seen in the ACA region of Nepal on hillsides with angles between 20° and 30°, and this sighting was officially recorded (Bista & Aryal, 2013) and between 24° to 42° in the Yellowstone area of North America (Mattson et al. 1992). The similar study of Red panda was found in (Bista et al. 2017) describe almost nearest average Slope or 31.56° ± 8.47° in Chitwan Annapurna Landscape.

6. CONCLUSIONS

The study focused on the DHR region, which encompasses a range of elevations from low to high lands. This research employs Species Distribution Models (SDMs) to create maps that illustrate the potential distribution of both species. The conclusion drawn from the study is that the suitable habitats for these sympatric species exhibit a high degree of overlap, with forests being the preferred land cover compared to other types of land use. The climatic variable plays a crucial role in determining the suitable habitat for the Asiatic black bear, whereas for the Red panda, it is determined by factors such as the Precipitation of the driest month, Precipitation seasonality (coefficient of variation), Mean temperature of the driest quarter, and Mean diurnal range (mean of monthly maximum temperature minus minimum temperature). Both species are affected due to human related factor or anthropogenic with compromise when modeling bioclimatic and anthropogenic variables. The study used MaxEnt modeling to map suitable habitats and areas of overlap for the Asiatic black bear and Red panda in the DHR. The models revealed shared areas and preferences for specific land cover types. As a result, this study successfully created habitat maps indicating the suitability of different areas for both species in the DHR. The results indicated that there are limited suitable habitats available for the occurrence of these species within the total area of the DHR. The study identified Gurjaghat and Nisheldhor sites in the DHR as having extensive habitats for the study species. The Distance from Water body and Ground cover strongly influence the habitat of Asiatic black bear in the DHR. The presence of Human settlements, Distance from Water body and Ground cover has a significant impact on where these Red panda can live. The study shows Asiatic black bear and Red panda prefer living in areas that have lots of Ground cover and are near water bodies.

7. RECOMMENDATIONS

Based on the results of entire study following recommendation are made:

- For more comprehensive investigations in the future, it is recommended to incorporate telemetry and GIS techniques in further research.
- Analyze the collected data using appropriate statistical method to determine the extent and nature of habitat overlapping between Asiatic black bear and Red panda.
- To minimize disruptions to natural habitats caused by humans, it is important to develop alternative methods of generating income.

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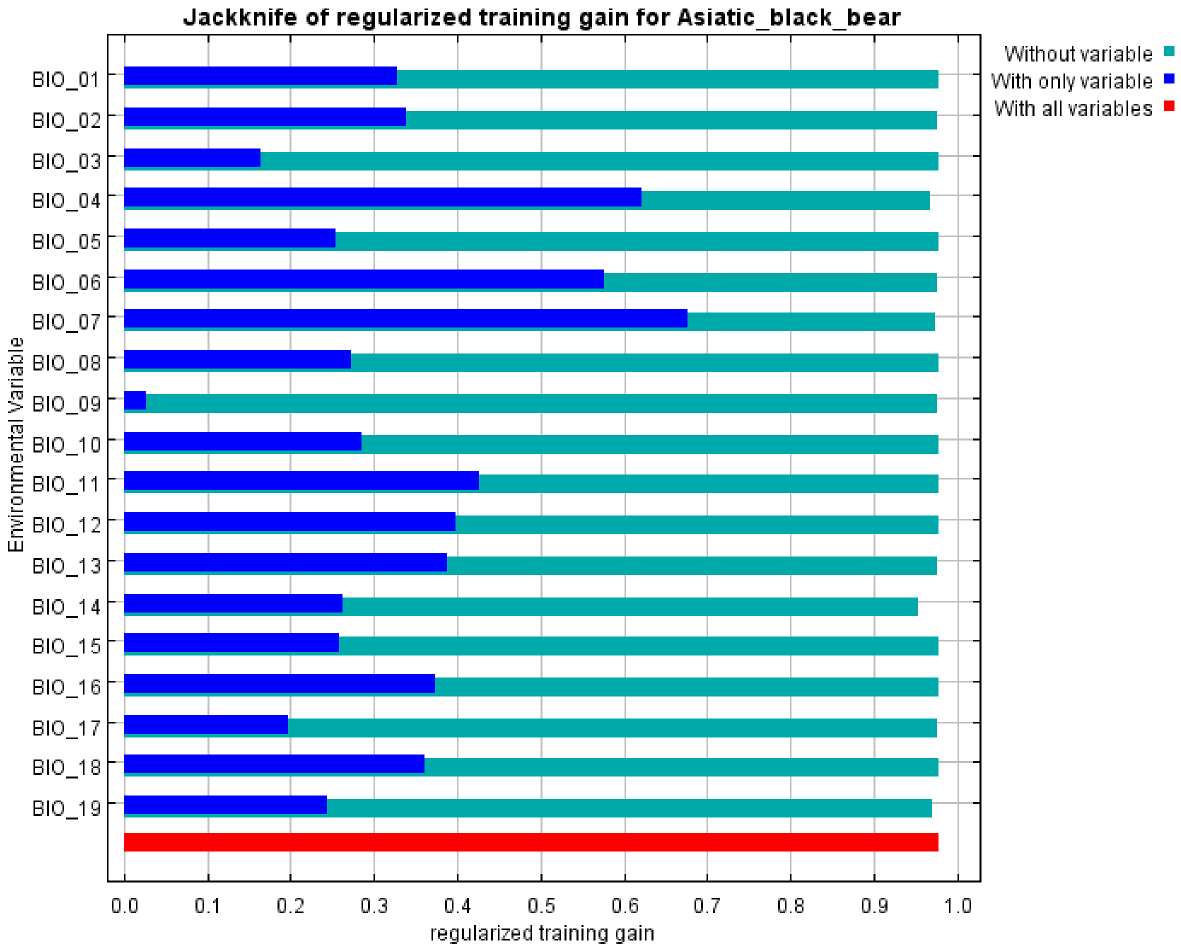
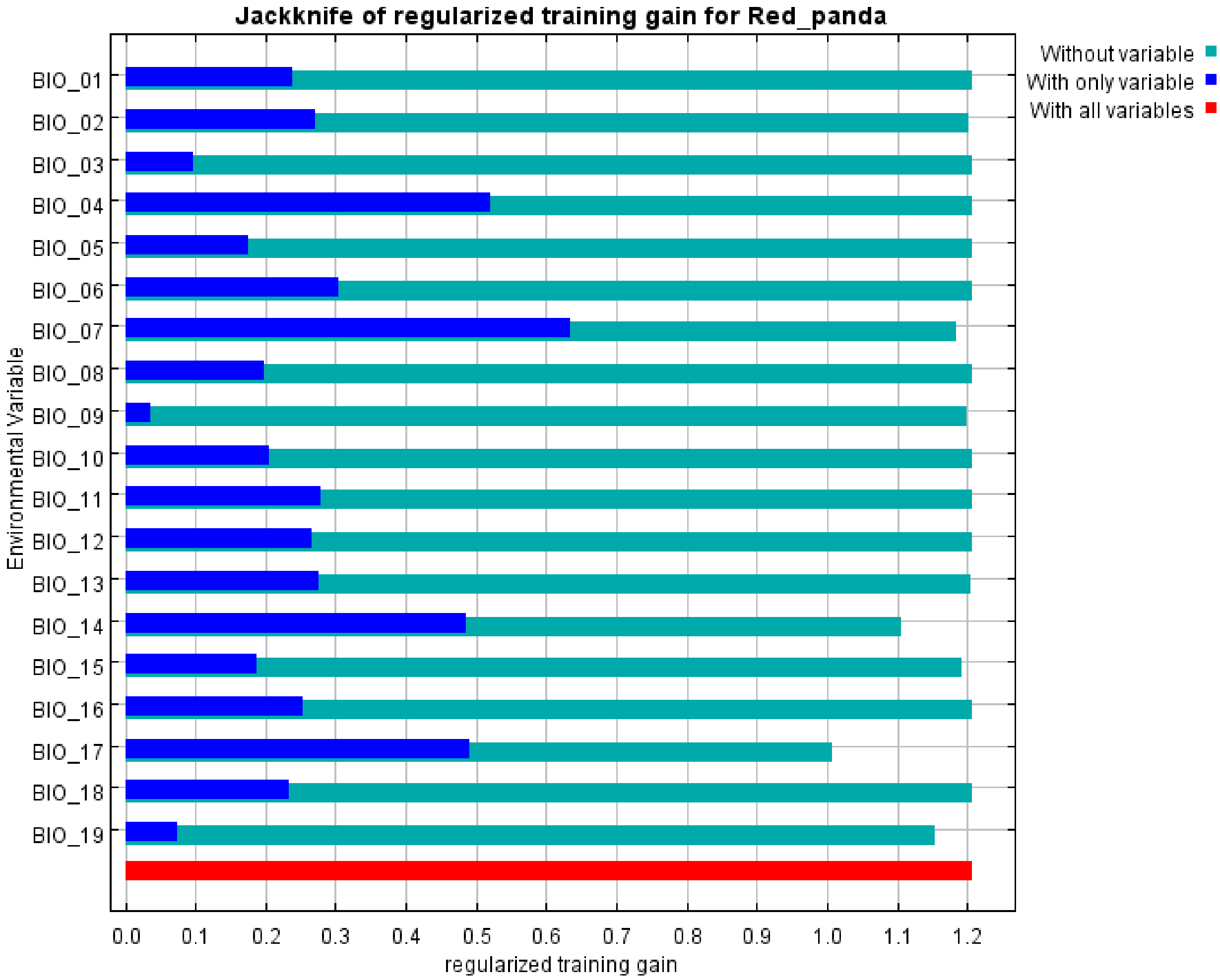
Appendices



Appendix 1: Jackknife test for selecting the variables for evaluating each predictor's relative contribution of environmental variables in predicting probable distribution of Asiatic black bear in DHR.



Appendix 2: Jackknife test for selecting the variables for evaluating each predictor's relative contribution of environmental variables in predicting probable distribution of Red panda in DHR

Codes	**Variables**
BIO_1	Annual Mean Temperature
BIO_2	**Mean Diurnal Range (Mean of Monthly (max temp - min temp)**
BIO_3	Isothermality (BIO2/BIO7) (×100)
BIO_4	Temperature Seasonality (standard deviation ×100)
BIO_5	Max Temperature of Warmest Month
BIO_6	Min Temperature of Coldest Month
BIO_7	Temperature Annual Range (BIO5-BIO6)
BIO_8	Mean Temperature of Wettest Quarter
BIO_9	**Mean Temperature of Driest Quarter**
BIO_10	Mean Temperature of Warmest Quarter
BIO_11	Mean Temperature of Coldest Quarter
BIO_12	Annual Precipitation
BIO_13	Precipitation of Wettest Month
BIO_14	**Precipitation of Driest Month**
BIO_15	**Precipitation Seasonality (Coefficient of Variation)**
BIO_16	Precipitation of Wettest Quarter
BIO_17	Precipitation of Driest Quarter
BIO_18	Precipitation of Warmest Quarter
BIO_19	Precipitation of Coldest Quarter Road Distance to nearest roads
Forest	**Forest**
Roads	**Distance to nearest Roads**
Settlement	**Distance to nearest Settlement**
Water body	**Distance to nearest Water body**
Aspect	**Aspect**
Slope	**Slope**

Appendix 3: Environmental layers used in species habitat overlapping Model of Red panda and Asiatic black bear. The highlighted variables were included in the model after testing for correlation between variables

Photo Galleries

Photo plate 1 with Inclinometer

Photo plate 2 Red panda scats

Photo plate 3 Data collection

Photo Plate 4 Red panda scats reported

Photo plate 5 Asiatic black bear paw sign

Photo plate 6 Red panda with GPS scats observation

Photo plate 7 Asiatic black bear
Scratch sign

Photo plate 8 Asiatic black bear
Scats

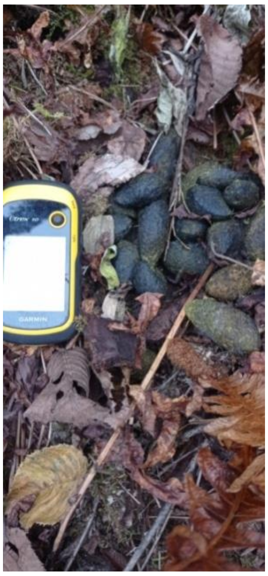


Photo plate 9 Red panda
Scats

Photo plate 10 Red panda

Photo plate 11Red panda Scats

A) Asiatic black bear

B) Red panda

Figure 18 :Jackknife test for evaluating the relative contribution of environmental variables in predicting the probable distribution of (A) Asiatic black bear and (B) Red panda model only with climatic variables. The blue, aqua and red bars represent the results of the model created with each individual, all remaining variables and all the variables respectively.

A) Asiatic black bear

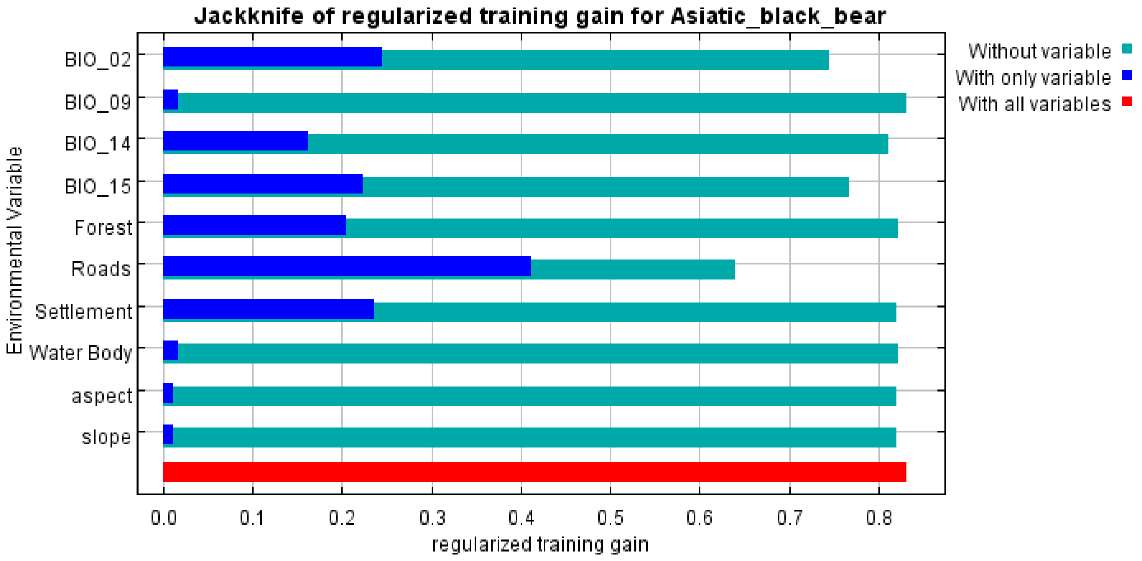


Figure 19 : Jackknife test for evaluating the relative contribution of environmental variables in predicting the probable distribution of Asiatic black bear model with climatic variables, Road, Settlement, Slope, Aspect, Water body and Forest. The blue, aqua and red bars represent the results of the model created with each individual, all remaining variables and all the variables respectively.

B) Red panda

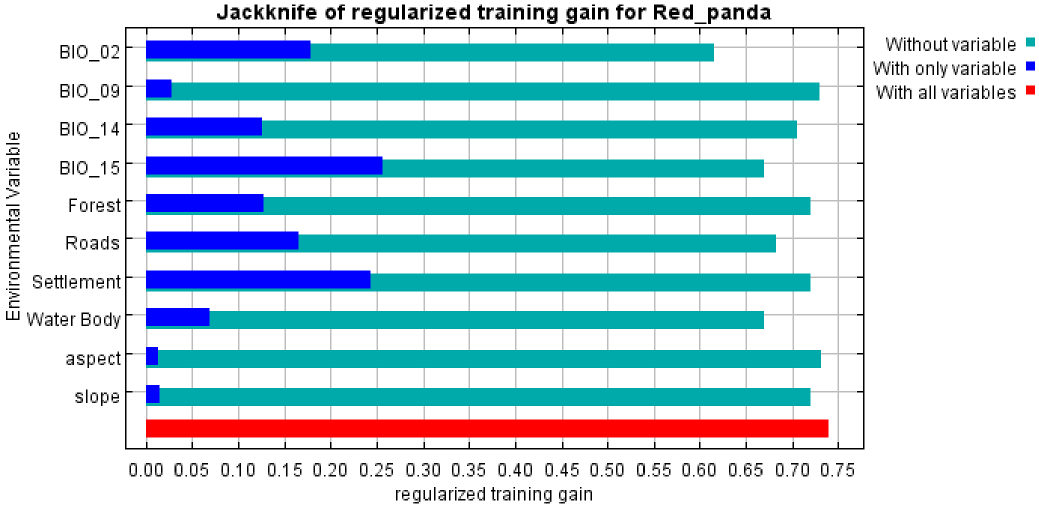


Figure 10 : Jackknife test for evaluating the relative contribution of environmental variables in predicting the probable distribution of Red panda model with climatic variables, Road, Settlement, Slope, Aspect, Water body and Forest. The blue, aqua, and red bars represent the results of the model created with each individual, all remaining variables and all the variables respectively.