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Habitat suitability modelling of *Melursus ursinus* (Shaw, 1791) (Mammalia: Carnivora) in the Chitwan National Park, Nepal

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Abstract

Sloth bear (*Melursus ursinus* Shaw), one of four species of bear found on the Indian sub-continent, has a geographical distribution across Nepal, India, and Sri Lanka. It is listed as Vulnerable under the International Union for Conservation of Nature Red List of Threatened Species due to the rapid decline of the global population. This decrease in *Melursus ursinus* presents a need for comprehensive research to predict and understand the distribution pattern. The present study predicts the habitat suitability and distribution pattern of *M. ursinus* in the Chitwan National Park, Nepal and its buffer areas. The entire study area was divided into 4 X 4 km grids. Within each grid, 10-meter radius plots were sampled for bear signs and habitat evaluation occurred at every 250 meters along a transect (1–1.5 km). Data on direct and indirect signs (diggings, pugmarks, scrapes, and scats) and other habitat use parameters of *M. ursinus* were collected. The study was carried out during the dry season (January to March 2019) in almost 57 grids of the study area. The calculated habitat suitability for *M. ursinus* determined that 25% of the total area was suitable, and the remaining 75% was less suitable habitat. Drainage, followed by slope and elevation, were found to be the important variables affecting the distribution of species in the study area and this model was found to be 88.5% accurate in terms of explaining the dependent variables. The findings of the present research will be useful for park managers, researchers, and academicians in the formulation of an appropriate conservation plan for this charismatic mammal species.

Key words: Buffer zone; distribution pattern; habitat threat; line transect; MaxEnt, Sloth bear

Introduction

The sloth bear, *Melursus ursinus* (Shaw, 1791), is one of the eight species of bear found across the world and one of four species of bear found on the Indian sub-continent (Servheen, 1990). It is endemic to the Indian sub-continent with a geographical distribution across Nepal, India, and Sri Lanka (Dharaiya, 2009). It has become extinct in Bangladesh and is reported to be rare in Bhutan (Garshelis et al., 2008).

In Nepal, *M. ursinus* was formerly reported across the Terai and Siwalik Hills but has been extirpated in some parts of the region (Garshelis et al., 1999a; Dharaiya et al., 2016). It is now reported from the Terai region, including the Chitwan National Park (CNP), Parsa National Park (PNP), Bardia National Park (BNP), and surrounding forests of Banke, Bara, Kailali, and Dang districts (Jnawali et al., 2011).

Melursus ursinus is omnivorous and its diet is comprised of social insects such as termites, ants, and fruits (Bargali et al., 2004). The sloth bear is found in different habitats ranging from wet evergreen forests to dry deciduous and degraded scrub forests (Philip et al., 2021). However, its abundance varies depending on the resource availability in different habitats (Tinoco et al., 2017). Generally, *M. ursinus* individuals aggregate in grassland due to the hard soil condition in upland forests which impedes the bears ability to excavate termite mounds by the beginning of the dry season (Ghimire and Thapa, 2014). In the case of the CNP of Nepal there is sharp segregation of various habitats which provide food for *M. ursinus* year-round (Garshelis, 2022). Likewise, it has been found that in the lowlands of Nepal, *M. ursinus* populations were either absent or occurred only in low densities in areas with high human use, despite the presence of high termite densities (Paudel et al., 2022). Thus, the abundance of *M. ursinus* may be influenced not only by resource abundances, but also by the level of human disturbance in an area (Wilson et al., 2006). Similarly, it has been found that *M. ursinus* feeds on various fruits such as *Ziziphus mauritiana*, *Ficus benghalensis*, and *Aegle marmelos* (Joshi and Singh, 2008). *Melursus ursinus* is an endangered species in Nepal and globally considered as Vulnerable under the IUCN Red List of Threatened Species. It is included in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (Dharaiya et al., 2016).

Habitat loss and poaching are primary causes of Sloth bear population decline (Johnsingh, 2003). Additionally, various anthropogenic activities such as depletion and fragmentation of natural habitats, trade in body parts, and the trade of live bear cubs for dancing have posed serious threats to Sloth bear populations across the entire range (Bargali et al., 2012). The only natural threat to *M. ursinus* is the Tiger *Panthera tigris tigris* and possibly the Leopard *Panthera pardus* (Joshi et al., 1999). There have been few previous studies on *M. ursinus* in the Chitwan National Park. Various studies on the ecology, habitat related diets, and sociobiology of *M. ursinus* were done by Joshi et al. (1995; 1997; 1999). Later, the occupancy of *M. ursinus* in the CNP was investigated by Ghimire et al. (2014). Research on the feeding ecology of *M. ursinus* based on scat analysis was conducted by Khanal et al. (2014). However, habitat suitability modelling for *M. ursinus* in the CNP has not been previously carried out.

Over the last few decades, with declines in the amount of natural habitat and in the numbers of associated wildlife, there has been significant development of various techniques for modeling the dynamics of wildlife populations and natural ecosystems (Western et al., 2009). Modeling is a crucial tool for understanding the habitat of highly threatened, long-lived species in a rapidly changing landscape using field-based variables and satellite-based data (Wang et al., 2020). As such, habitat suitability studies are usually defined as using multivariate models in conjunction with GIS methods to create distribution and suitability maps (Guisan and Zimmermann, 2000). The primary use of habitat modeling in management and conservation planning is to predict the spatial distribution of suitable habitats for desired species in a given landscape. Among all the models, the most commonly used model for wildlife habitats are the habitat suitability index, linear regression, Generalized Linear Regression Models (GLMs), Generalized Additive Models (GAMs), regression tree analysis, and Bioclimatic prediction system (BIOCLIM) (Pun et al., 2022). All of these models are associated with statistical assumptions. The use of these modeling techniques, coupled with computer-based, spatially related data and GIS, provides a powerful quantitative means to predict the distribution and abundance of species and wildlife assemblages across the landscape with high reliability (Norton et al., 1992).

Moreover, Species Distribution Models (SDMs) can also be classified by their algorithms as regression methods such as GAM, GLM, and multivariate adaptive regression splines (MARS); machine-learning methods such as Artificial Neural Networks (ANN), Boosted Regression Trees (BRT), Maximum Entropy Maxent (MEM), and Random Forest (RF); classification methods such as Classification Tree Analysis (CTA) and Flexible Discriminant Analysis (FDA); and enveloping methods such as Surface Range Envelope (SRE) and BIOCLIM (Hallgren et al., 2019). There are numerous statistical models that are used to predict the distribution of a species (Franklin, 2009). In addition to traditional regression methods (Boyce and McDonald, 1999) (e.g., GLM, GAM (McCullagh and Nelder, 1989)), algorithmic modeling based on machine learning (e.g., ANN (Ripley, 1996), MaxEnt (Philips et al., 2006)) has grown in popularity. MaxEnt will estimate the ecological niche in the environmental space (Elith et al., 2011) and project it onto the geographical space to derive the probability of presence for any given area (Elith and Leathwick, 2009). Moreover, according to Phillips et al. (2006), this software is used for finding the maximum entropy distribution probability and to predict the potential distribution of a target species under various conditions when it satisfies maximum entropy. It can be used when distribution data are insufficient as MaxEnt requires only information about the occurrence of a species for the purpose of predicting the most suitable habitat (Pun et al., 2022). As such, this model is beneficial because it can achieve accurate classifications with available data only. MaxEnt predicts the potential distribution of the target species by analyzing location data, a dependent variable, from the function of different environmental variables (Byeon et al., 2018).

Location data, obtained as occurrence data from a field survey, and other information such as land use, land cover, forest type, distance, geographical features, and climatic data can be used to provide environmental variables.

Very few studies have attempted habitat modeling for *M. ursinus*. Occurrence data can be used in the development of models based on future climate scenarios to predict its future distribution. The present study will provide valuable insights for the conservation of *M. ursinus* for park managers, wardens, researchers, and academicians to formulate appropriate conservation and research plans. The main objective of the study was to assess the distribution pattern and habitat use of *M. ursinus* in the Chitwan National Park and to develop a habitat suitability model for *M. ursinus* in the CNP using MaxEnt.

Material and Methods

Study area

The CNP and its buffer zone are situated in the southern part of central Nepal, which spreads over Chitwan, Nawalparasi, Parsa, and Makawanpur districts (Fig. 1). The geographical location of the CNP is between 27°20'19" to 27°43'16" N latitude and 83°44'50" to 84°45'03" E longitude. The average annual rainfall in the park reaches 2,600 mm with approximately 80% of that occurring within the four months (June to September) of the rainy season (DNPWC, 2010).

Four vegetation types are predominantly found in the CNP. Firstly, Sal (*Shorea robusta*) is dominant and it represents a climax species, comprising 70% of the park and is mainly found on well-drained soils (Thapa, 2014). Secondly, riverine forest, which represents 7% of the park, is found in areas with excess moisture. The common species in this category are *Dalbergia sissoo*, *Accaaia catechu*, and *Bombax ceiba.* Thirdly, grassland makes up 20% of the park. Finally, Chir pine (*Pinus roxburghii*), which is found in the hills, accounts for the remaining 3% of the park (Straede and Helles, 2000). CNP provides habitat to diverse fauna among which 68 species of mammals, 576 species of avifauna, 49 species of herpetofauna, 126 species of fishes, and many species of invertebrates are known (CNP, 2019).

Sampling design

The fieldwork for assessment of the distribution and habitat suitability mapping of *M. ursinus* was carried out from January 2019 to March 2019. A preliminary study was followed by direct and indirect observations, along with consultation with key informants and key stakeholders in the study site. For the methodology, the area of the CNP along with its buffer zone areas were divided into equal grids of 4 X 4 km (approximately the home range size of the species (Hines et al., 2010)) using ArcGIS 10.5 software, so as to cover the entire area of the CNP as well as the buffer zone. Hence, in the case of the CNP, 50% of the total grids were selected for sampling based upon the type of vegetation and their proportion within the park boundaries and from the buffer zone areas with the help of secondary information and consultation with stakeholders (Acharya et al., 2018). Twenty grids (4 X 4 km) were sampled based on the proportion of the vegetation types. Line transects of 1–1.5 km were laid in every sampled grid. In the selected grids, transects were sampled to assess bear sign encounter rates. The GPS location of *M. ursinus* visual encounters and signs (scats, claw marks, digging, scrapes, other) were recorded. At every 250 m along the transect, circular plots (10 m radius) were sampled for habitat parameters including food trees and anthropogenic disturbances (Acharya et al. 2018). With the sampling procedure, a total of 70 km of transect walks were done in 57 grids, which yielded a total of 133 evidences for the presence of *M. ursinus*. The most frequently detected sign was digging (n= 113). This was followed by scat (n= 11). Similarly, a total of five scrapes and two pugmarks were found in the study area. The signs for *M. ursinus* were found in 32 grids out of the total surveyed grids. Of these detected grids, 24 grids fall under the core area and the remaining 8 grids fall under the buffer zone areas of the CNP (Fig. 2). Five major tree species including *Aegle marmelos*, *Ziziphus* spp., *Bridelia retusa*, *Ficus semicaudatum*, and *Cassia fistula*, which are food plants for *M. ursinus* (Joshi et al., 1999), were assessed in the sample segments along the transect.

Data analysis

The distribution pattern of *Melursus ursinus* was determined by calculating the ratio of variance and mean (S^2/a) as described by Odum (1996), which is based on the Poisson distribution, where the variance (S^2) is equal to the mean value (a). Similarly, for this study, the signs of *M. ursinus* such as scats, diggings, and scrapes in each habitat type were recorded and used to determine the distribution pattern. If $S^2/a= 1$, it means there is a random distribution, if $S^2/a < 1$, it has a regular distribution, and if $S^2/a > 1$, it indicates a clumped distribution (Sadadev et al., 2021).

Chi-square test (χ2)

Similarly, the Chi-square test for goodness of fit was used to determine whether the direct sightings and indirect signs of *M. ursinus* are distributed significantly in all four different habitat types (Nugraha et al., 2021). It was performed by setting the hypothesis that *M. ursinus* was uniformly distributed in all habitat types in the CNP and its buffer zones. Chi-Square (χ2)= Σ (x-a) 2/a (where x= observed or sample value; a= expected value or mean value) (Ghimire and Thapa, 2014).

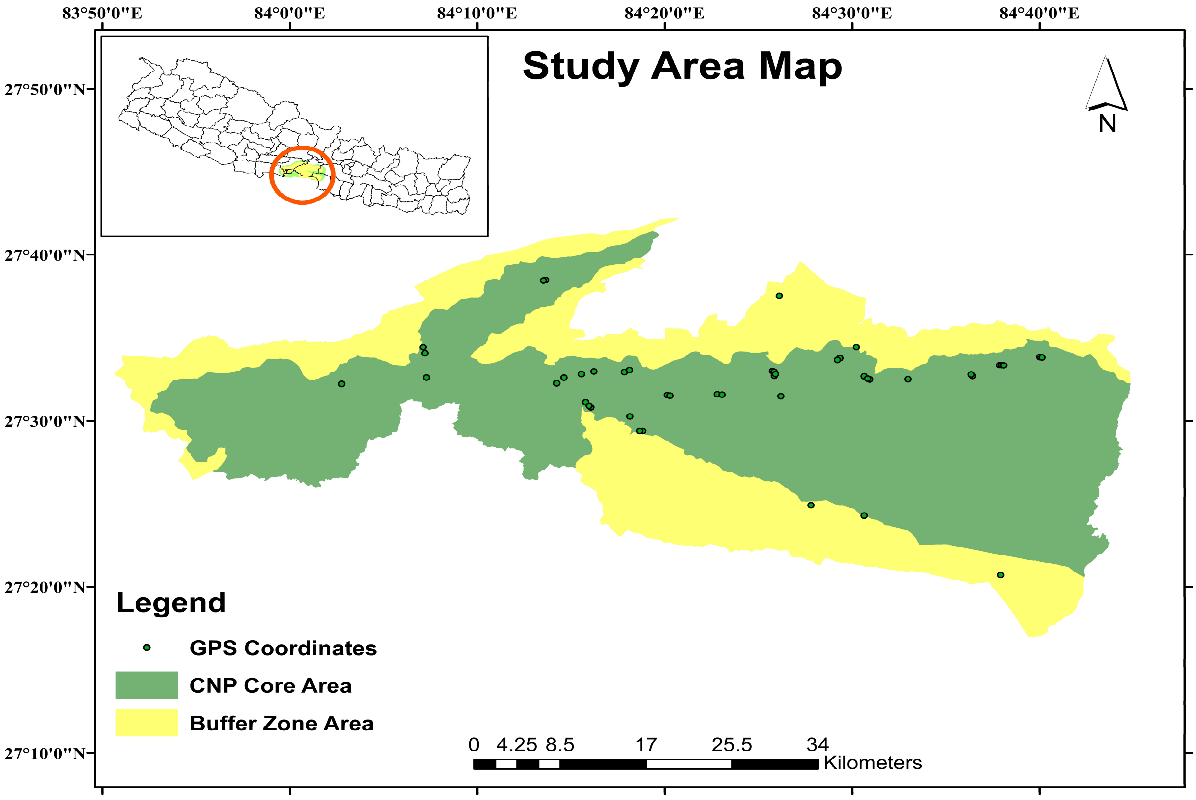

Figure 1: Study area map of the Chitwan National Park and its buffer area.

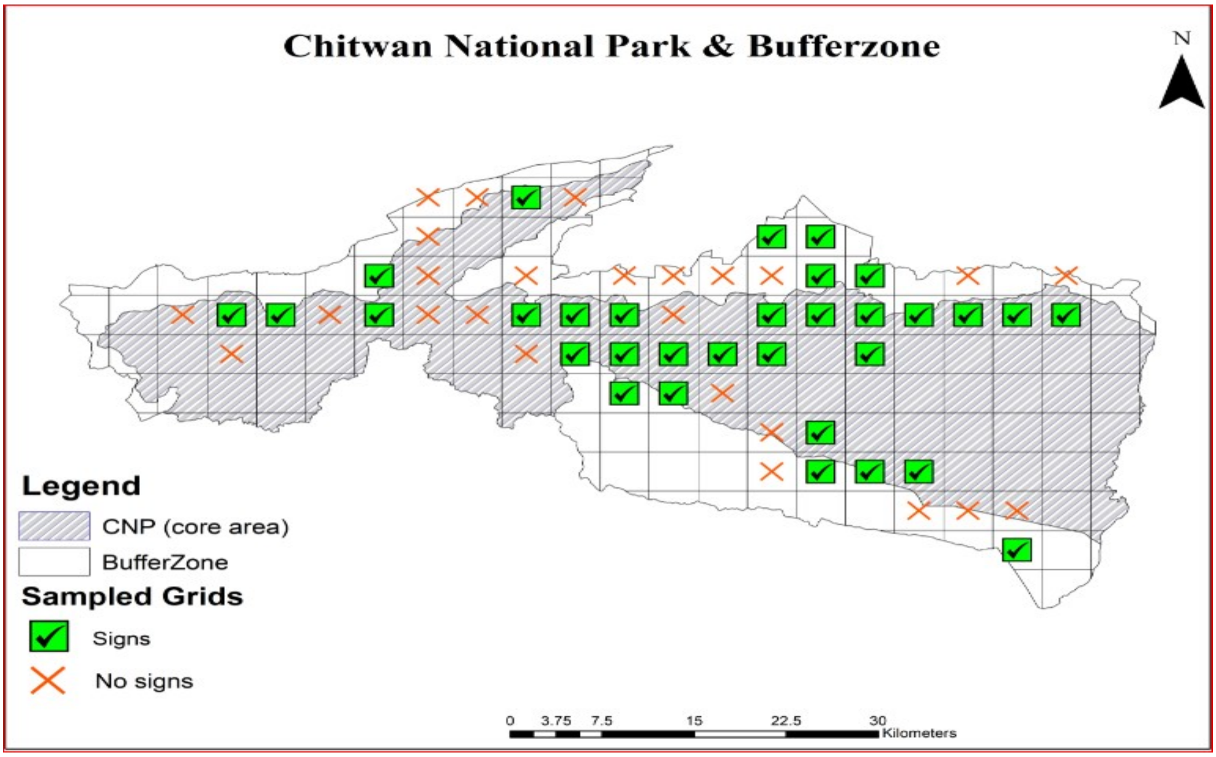

Figure 2: Total sampled grids in the study area of *Melursus ursinus* in the Chitwan National Park, Nepal.

Ivlev's Electivity Index

For determining the habitat use of *M. ursinus* in CNP, the presence or absence of the species in each segment of the transect was used. The habitat use of *M. ursinus* was calculated by following the method of Ivlev's index of electivity (IEI) as follows: IEI= U – A / U + A where U is the total number of signs of a given species in the particular habitat type and A is the availability of that habitat type out of total area (Ivlev, 1961). Thus, for a positive value of IEI we can assume that it has more use than availability, for zero we can assume that use is in proportion to availability, and for negative value we can assume less use than availability (avoidance) (Patrick, 2014).

Habitat suitability modelling

The MaxEnt algorithm 3.4.1 version is a commonly used SDM tool by conservation practitioners for the purpose of predicting the distribution of a species from a set of records and different environmental predictors (Elith et al., 2011; Pun et al., 2022). For running this software various data and tools are needed which are as described below in the context of the present study.

Presence data

A field visit was conducted from January to March 2019, in which the GPS coordinates of the presence signs of *M. ursinus* were collected from the sampled grids (along the transect and plots). In total, 49 presence points of *M. ursinus* were used as input for maximum entropy modelling for the species distribution (Fig. 1). For environmental information, 19 bioclimatic variables were derived from globally interpolated datasets (source: http://www.worldclim.org) representing annual trends, seasonality, and extreme or limiting environmental factors. These variables were used for the modelling study because they are presumed to be the most relevant to animal existence (Pearson and Dawson, 2003; Pearson, 2007). These metrics were taken from monthly temperature and rainfall climatologies and represent biologically meaningful variables for characterizing a species range (Buermann et al., 2008). The other six physical variables were taken from different sources: land use land cover (LULC) data was obtained from the International Centre for Integrated Mountain Development (ICIMOD), aspect and slope were taken from Shuttle Radar Topography Mission (SRTM) of the United States Geological Survey (USGS) site (earthexplorer.usgs.gov), drainage and road data were obtained from DIVA-GIS (diva-gis.org), and the human influence index (HII) was obtained from MODIS (https://modis.gsfc.nasa.gov). The various bioclimatic variables used, along with other physical variables, are given in Table 1.

Multicollinearity test

The Pearson correlation analysis was performed for the 19 bioclimatic variables and six physical variables (slope, aspect, LULC, drainage, road, and human influence index) using the software Ecological Niche Models (ENM) Tools version 1.4.4 (Warren et al., 2011) to ensure the quality of the final habitat suitability models and to reduce potential over parameterization (Merow et al., 2013). As suggested by previous studies, all variables with correlations larger than ± 0.75 were evaluated to retain only those most relevant to the species' ecology (Kumar et al., 2009; Kumar and Stohlgren, 2009; Padalia et al., 2014).

Model validation

The prediction accuracy of MaxEnt was determined through receiver operating characteristics (ROC) analysis due to its wider range of applications in modelling studies (Wang et al., 2018). The ROC plot can be made by placing the sensitivity values (true positive fraction against false positive fraction) for all available probability thresholds. A good model is indicated when a curve maximizes sensitivity against low false positive fraction values and is generated by computing the area under the curve (AUC) (Phillips and Dudík, 2008). Based on Franklin (2010), an AUC value of closer to 1 is considered a good model, which also shows total agreement between the model and test data. An AUC value close to 0.5 is considered no better than random, while predictive ability is considered to be sound with an AUC value greater than 0.8 (Franklin, 2010).

Table 1: Bioclimatic and physical variables.

S. No.	Bioclimatic and physical Variables	Codes
1	Annual Mean Temperature	bio1
2	Mean Diurnal Range (Mean of monthly (max temp - min temp))	bio2
3	Isothermality (BIO2/BIO7) (* 100)	bio3
4	Temperature Seasonality (standard deviation *100)	bio4
5	Max Temperature of Warmest Month	bio5
6	Min Temperature of Coldest Month	bio6
7	Temperature Annual Range (BIO5-BIO6)	bio7
8	Mean Temperature of Wettest Quarter	bio8
9	Mean Temperature of Driest Quarter	bio9
10	Mean Temperature of Warmest Quarter	bio10
11	Mean Temperature of Coldest Quarter	bio11
12	Annual Precipitation	bio12
13	Precipitation of Wettest Month	bio13
14	Precipitation of Driest Month	bio14
15	Precipitation Seasonality (Coefficient of Variation)	bio15
16	Precipitation of Wettest Quarter	bio16
17	Precipitation of Driest Quarter	bio17
18	Precipitation of Warmest Quarter	bio18
19	Precipitation of Coldest Quarter	bio19
20	Slope	Slope
21	Aspect	Aspect
22	Land Use Land Cover Change	LULC
23	Human Inference Index	HII
24	Road	Road
25	Drainage	Drainage

Satellite images of the study area and map were downloaded from USGS Earth Explorer LANDSAT data (https://gisgeography.com/usgs-earth-explorer-download-free-landsat-imagery/) and the shape file of CNP was obtained from the National Trust for Nature Conservation (NTNC) office. The MaxEnt model was run multiple times by setting up the parameters (replicates, random test percentage, and number of iterations) of MaxEnt to a different value for each time in order to obtain maximum accuracy. The Environmental Niche Modeling (ENM) tools were used for each environmental layer by using the Pearson Correlation Coefficient (r) to test the cross-correlation. The results of the test showed that 13 of the 25 environmental and physical variables had a correlation coefficient value greater than ± 0.75 and thus were highly correlated (Skevington et al., 2004). Hence, they were removed, leaving 12 variables for use in the model.

The maximum number of background points taken was 10,000. Linear, quadratic, product, categorical threshold, and hinge features were used for running MaxEnt. Predictions from 100 models were averaged to produce the final map of probability for the presence of *M. ursinus* with the replicated type bootstrap. The regularization multiplier was set to 0.1 for reducing model over fitting (Phillips et al., 2004). The rest of the parameters were left as default. Based on different variables, MaxEnt predicts the high values for grid cells in the data which are suitable for the species occurrence. The map showing the distribution of *M. ursinus* was generated in ArcGIS where the shape file (.shp) was first converted into an ASCII file (.asc) through the conversion tool. The average .asc file generated by the MaxEnt model was converted into the raster format to show the distribution of *M. ursinus* in the study area, which was based on 49 geocoordinates and a set of 25 environmental and physical variables.

Results

Distribution pattern

Most observations of signs of *M. ursinus* was recorded from the Sal (*Shorea robusta*) forest (41%), followed by the mixed forest (28%), riverine forest (8%), and grassland habitat (23%). The major proportion of signs was recorded from the Sal forest, as this type of habitat formed the major proportion of the study area (Fig. 3).

Chi-square test for goodness of fit (χ2)

In this study, signs of *M. ursinus* were found in all types of habitats. However, the variance to mean ratio calculation revealed a clumped distribution pattern of *M. ursinus* ($S^2/a = 7.21 > 1$). The value obtained from the Chi-square test was (χ2) cal= 28.87. The value (χ2) of the tab with 10% level of significance at degree of freedom (4–1) was 6.27, which was less than the calculated value of 28.87. Therefore, the research hypothesis of uniform distribution of *M. ursinus* in the study area was rejected (Ghimire and Thapa, 2014).

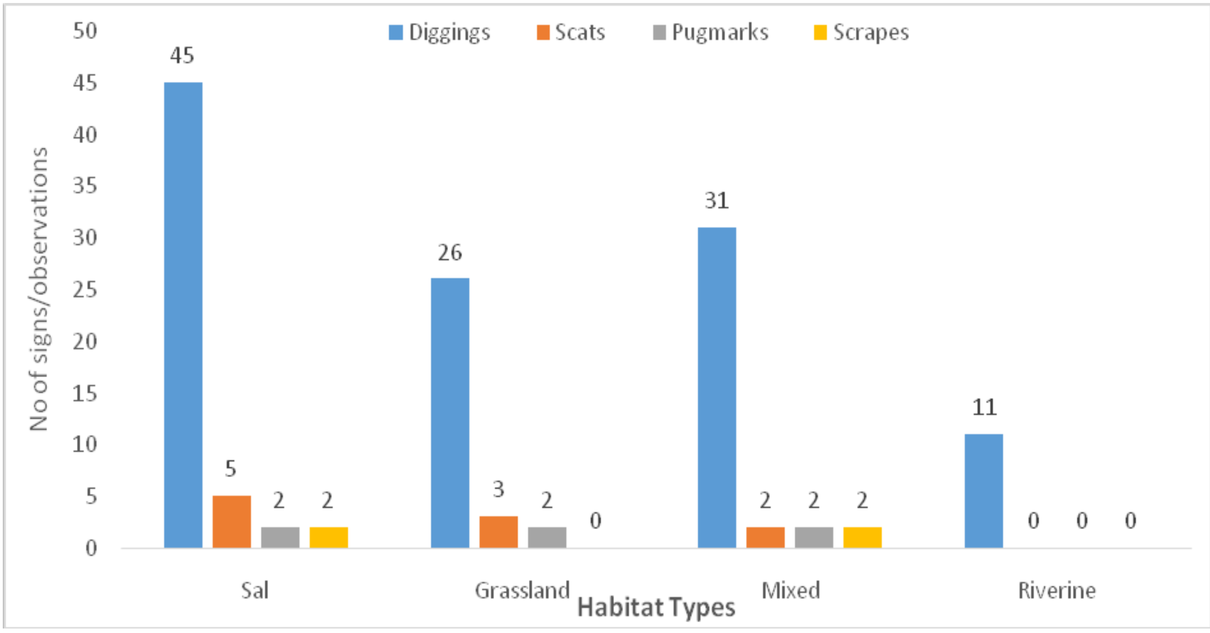

Figure 3: Total number of signs/observations of *Melursus ursinus* in different habitat types.

Habitat suitability modelling

From the reclassified mean and standard deviation from MaxEnt's logistic output, it suggests that area of approximately 1,258 km^2 as less suitable for *M. ursinus*. This represents 75% of the total study area. An area of 432 km^2 (25%) was suggested to be suitable for *M. ursinus*. The modelled distribution of low and high habitat suitability for *M. ursinus* in the CNP is shown in Figure 4. According to this map, the eastern and southern parts of the study area are predicted to be less suitable in terms of *M. ursinus* habitat.

Ivlev's Index of electivity

The CNP is a composite of different types of forests. However, in the present study four types of habitats were primarily considered, namely Sal (*Shorea robusta*) forest, mixed forest, riverine forest, and grassland. Out of the total 228 locations surveyed, 172 occurred within the Sal forest, 20 in mixed forest, 12 in riverine forest, and 24 in the grassland habitat. The IEI index revealed that the mixed forest was found to be the most preferred (IEI= 0.29) habitat by *M. ursinus*, followed by the grassland (IEI= 0.12). Riverine forest and Sal forest were the habitats less preferred by the species (IEI= -0.04 and -0.52 respectively); but these were not totally avoided.

Analysis of the Receiver Operating Characteristic (ROC) curve

According to Swets (1988), categorized models with values >0.9 are highly accurate for prediction modeling. The AUC will provide a single measure of model performance that is independent of any particular choice of threshold. The MaxEnt model output provides adequate results with the given set of training/test data and the model fitness as measured by the area under the receiver operating characteristics (ROC) curve (Padalia et al., 2014). The average training AUC for the replicate runs was 0.885, and the standard deviation was 0.016 (Fig. 5), which indicated that the model performed well with high accuracy (Swets, 1988).

Figure 6 depicts the results of the jackknife test of AUC where drainage was indicated as a main variable that influences the distribution of *M. ursinus*. Other important variables that have an impact on *M. ursinus* distribution are slope, elevation, bio_4 (temperature seasonality), and aspect. The values displayed are averages of replicated runs.

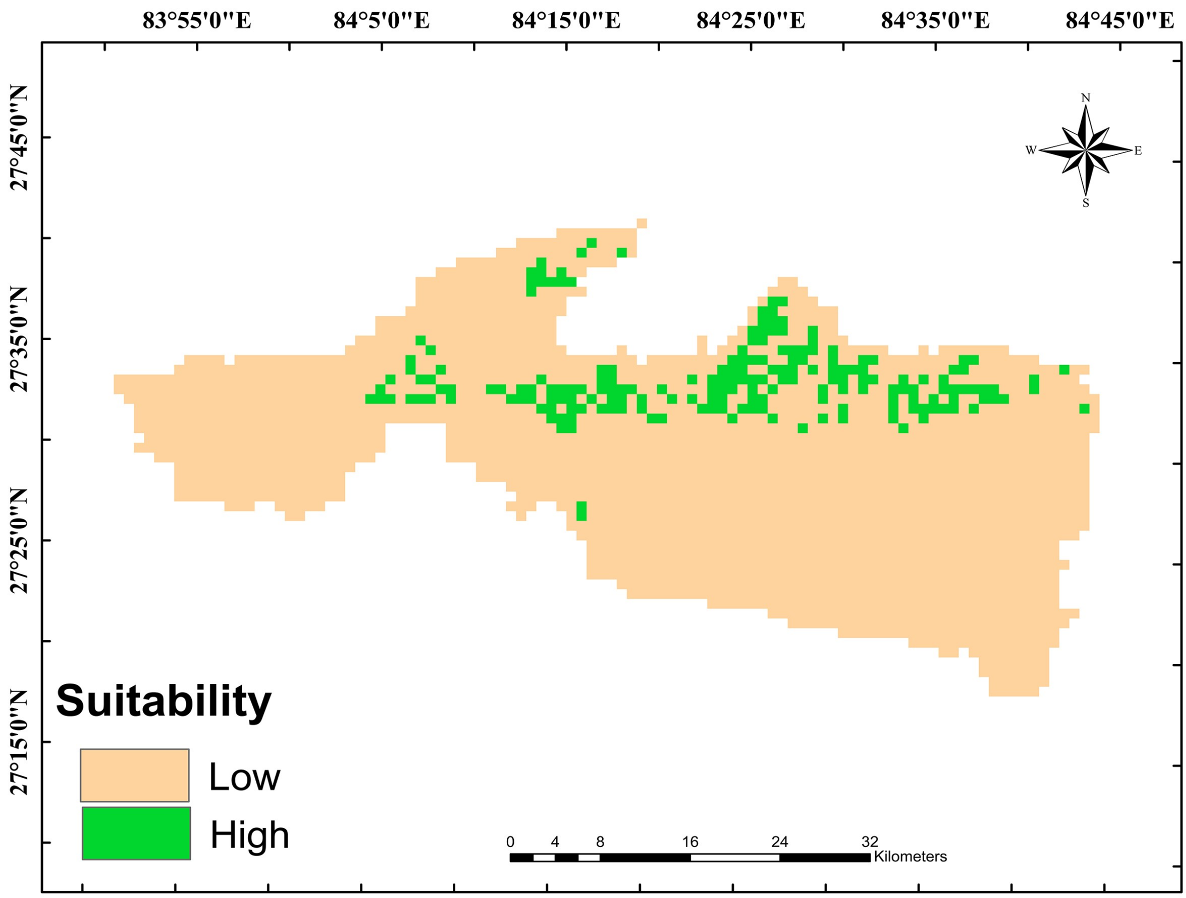

Figure 4: Habitat suitability map of *M. ursinus* in the Chitwan National Park.

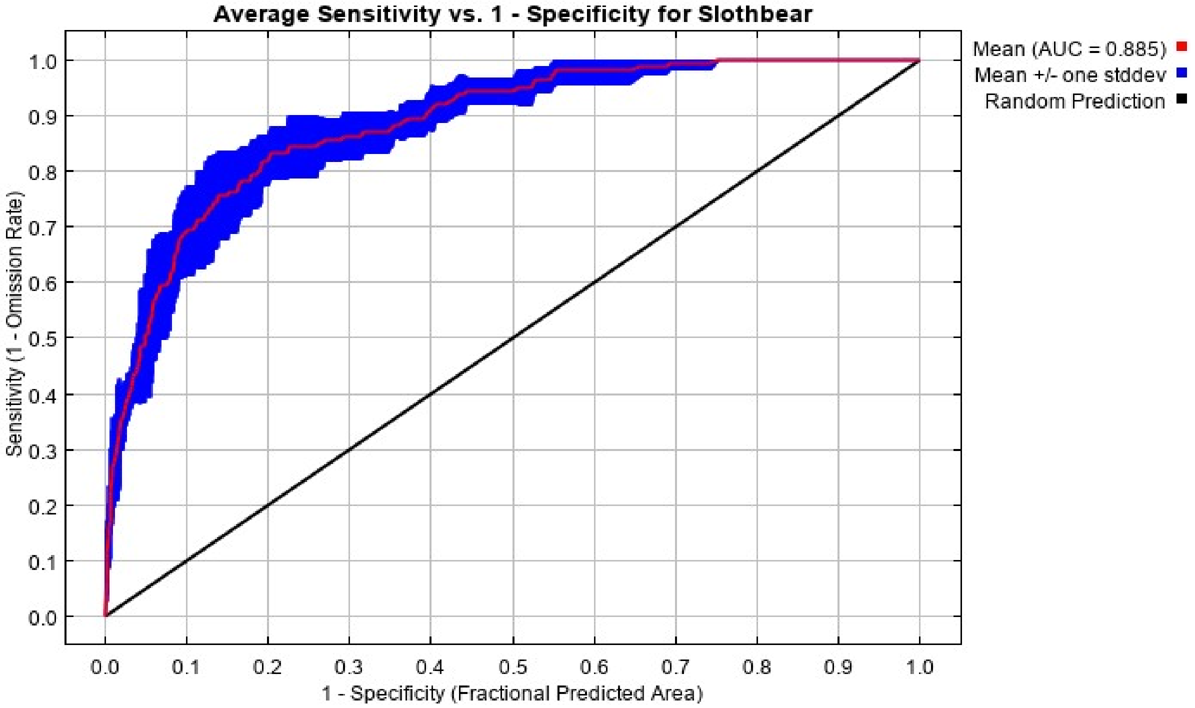

Figure 5: AUC curve for suitability modeling of the present study.

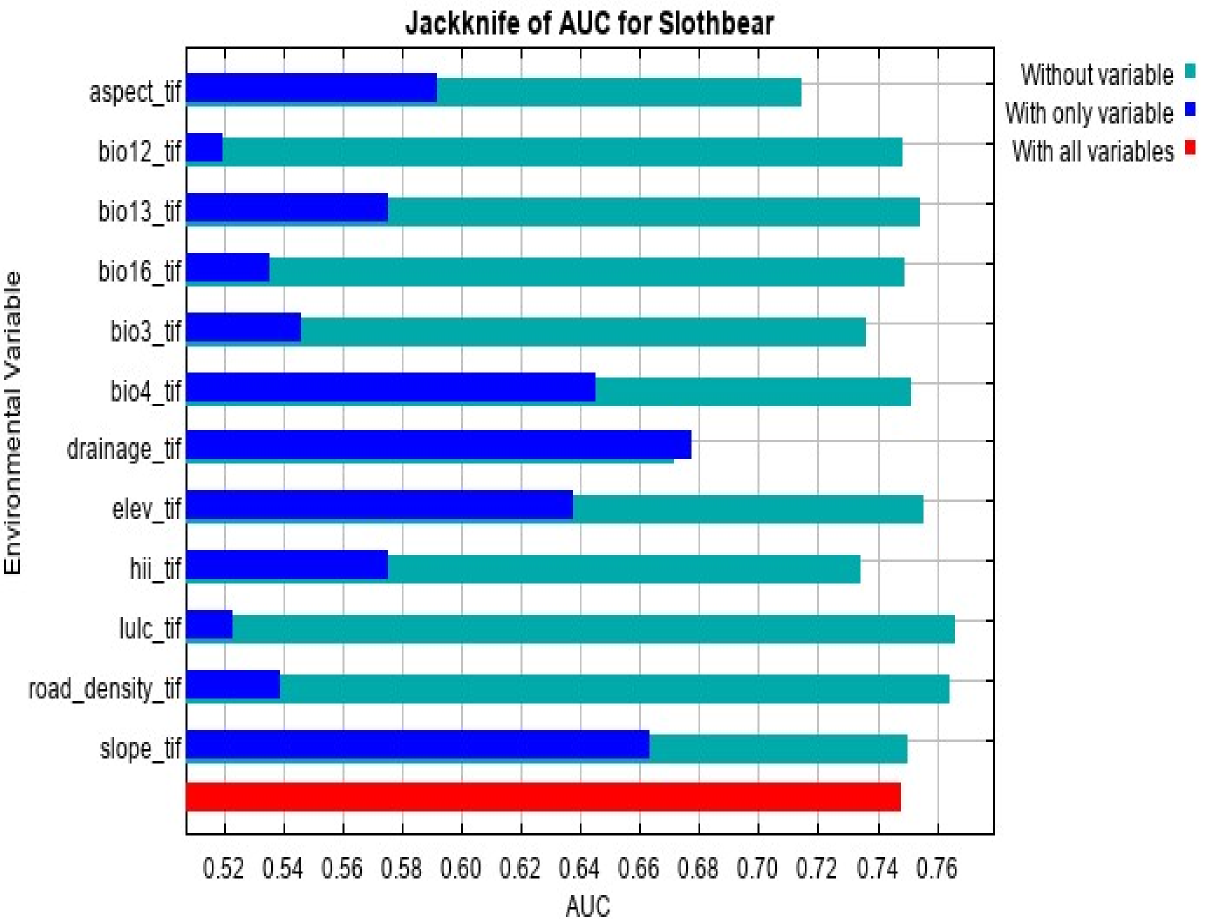

Figure 6: Jackknife test of importance of variable in model of the present study.

The relative importance of climate variables used for predicting the climate niche of *Melursus ursinus*

Based on the Jackknife test of training data, the environmental variable that showed the highest percentage contribution has the highest impact in determining the distribution of *Melursus ursinus*. In accordance with all the 100 model runs, it can be said that water drainage and aspect have the highest impact in determining the distribution of *Melursus ursinus*. Along with those, slope, temperature seasonality, elevation, isothermality, road, LULC, precipitation of wettest month, human influence index, precipitation of wettest quarter, and annual precipitation also play important roles in determining the distribution of *Melursus ursinus* (Table 2).

Discussions

The results of the present study has relevance to the study conducted by Ghimire et al. (2014), who also found a clumped type of distribution pattern of *Melursus ursinus* in the CNP. A clumping pattern is the most common pattern in nature when individuals are considered (Odum, 1996). In nature, resources such as food availability, water sources, and cover are not distributed uniformly, leading to the uneven distribution of species (Ghimire and Thapa, 2014). In the case of CNP, there is a sharp segregation of various habitats that provide food for *M. ursinus* throughout the entire year (Garshelis et al., 1999a). The pattern of clumped distribution resulted from the sloth bears' proclivity to visit areas with higher food availability (Bauer et al., 2013). In India, the patterns for the distribution of *M. ursinus* are determined by the presence of deciduous forests, scrub, and barren land areas (Rathore, 2008). Despite the presence and extent of protected areas being considered as a positive factor for the distribution of *M. ursinus*, forest cover has the greatest positive influence. Therefore, *M. ursinus* individuals are not restricted to the protected areas but occur widely in unprotected, multi-use, and reserve forests also (Athreya et al., 2013; 2014).

Seasonal variation, availability of food, shelter, and vegetation cover determine the quality of the sloth bear habitat. The availability of fruiting trees, shrub densities, water, termites and ants directly influence the habitat use (Akhtar et al., 2004). In the study conducted by Akhtar et al. (2004), they found that most of the available habitat were the mixed forest (29.2%) and scrubland (22.6%), whereas plantations represented the least available habitat type and the goodness-of-fit test showed that *M. ursinus* use of each habitat category differed from the occurrence of habitat categories within the study area. Thus, the result was that the occurrence of bear signs was high in the Sal (*Shorea robusta*) forest, which was followed by land near water bodies, plantation, and mixed forest (Akhtar et al., 2004).

Table 2: Contribution (%) and permutation importance by different variables

Variables	% Contribution	Permutation importance
Drainage	21.4	18.4
Aspect	18.4	17.2
Slope	13.7	14.5
bio_4 (temperature seasonality)	11.9	10.9
Elevation	8.1	11.5
bio_3 (isothermality)	7.9	3.8
Road	6.7	6.2
LULC	4.8	3.4
bio_13 (precipitation of wettest month)	2.4	4.1
Human Influence Index	2.3	3.1
bio_16 (precipitation of wettest quarter)	1.9	6
bio_12 (annual precipitation)	0.4	0.9

Jena et al. (2017) found that various environmental variables contribute to the spatial distribution of *M. ursinus* in the Similipal Biosphere Reserve where the mean diurnal temperature (bio_2) range has a great effect on the distribution pattern of *M. ursinus* and isothermality (bio_3) has less effect on the distribution pattern. Any certain change in the major contributing environmental parameters can lead to a great fluctuation in habitat as well as in distribution pattern. However, in the present study it was found that drainage has the greatest impact on the distribution pattern of *M. ursinus* in the CNP, followed by aspect. Similarly, Jena et al. (2017) found that about 10% of the similipal was suitable as habitat for Sloth bear. Likewise, according to the study conducted by Jena et al. (2017), it has been found that *M. ursinus* is very intensively distributed in the southwestern part of the Similipal Biosphere Reserve. However, present study shows that about 25% of the total area has been found suitable for *M. ursinus*. Similarly, Khosravi et al. (2016) used MaxEnt modeling for the Goitered gazelle *Gazella subgutturosa* (Güldenstädt) in Central Iran where they found that the distribution of potential habitats at a 250 m grid size was strongly influenced by bioclimatic data, vegetation type, density, and elevation. Among the input environmental variables based on the jackknife analysis results, bio_1, vegetation type, elevation, bio_2, and density of vegetation type 3 were the five most effective predictors when used by them (Khosravi et al., 2016).

According to Haghani et al. (2016) to evaluate the habitat suitability of the Asian houbara *Chlamydotis macqueenii* (Gray) in Iran using maximum entropy models, they found that the most important factors out of a total of 42 environmental and climate variables affecting habitat suitability of the species in all seasons were the distance to hill, the vegetation type of *Artemisia-Gymnocarpus*, distance to the slope (8–12%) in the Nayband Wildlife Refuge; distance to the vegetation type of *Artemisia aucheri*, distance to the Land Passion, and distance to the dry land farming in the Petregan Region, respectively. Similarly, from the Jackknife test, they evaluated the predictor variables and DEM, precipitation, and land cover were found to be the most important variables for their study (Haghani et al., 2016). Meanwhile, this type of research is necessary for the conserve of the Sloth bear and its habitat to prevent further population declines. Likewise, this kind of research will be helpful in translocating the animals to a suitable habitat to maintain a viable population and adequate genetic diversity. Furthermore, with the help of habitat suitability modelling, we can identify favorable distribution sites of this species, which will help to concentrate conservation efforts. This will lead to effective conservation of these animals as well as help to prevent the investment of resources in areas that are less suitable.

The present study concluded that the distribution pattern of the Sloth bear was of the clumped type in the CNP and its buffer areas. Most of the signs that were encountered were diggings, scats, scrapes, and pugmarks. The habitat uses by the Sloth bear, the IEI index of the mixed forest was high followed by grasslands. Similarly riverine and Sal forest have negative IEI values, which indicates that Sloth bears mostly preferred mixed forest, followed by grasslands. Regarding the habitat suitability for the Sloth bear, it was found that about 25% of the total area is suitable and the remaining 75% of the total area is less suitable based upon the different climatic and physical variables that were taken into consideration for the preparation of the map by using MaxEnt software. Based upon the Jackknife of AUC, drainage is an important variable that influences Sloth bear distribution. Similarly, other important variables are slope, elevation, temperature seasonality (bio_4), and aspects that have major roles in affecting the distribution of the Sloth bear.

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Conflict of interest

The authors declare that there are no conflicting issues related to this research article.

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