Factors Affecting Distribution of Blackbuck (*Antilope cervicapra*) in India and Nepal

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In partial fulfilment of the requirements for the award of the degree of Master of Science in Zoology with special paper Ecology & Environment

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Declaration

I hereby declare that the work presented in this dissertation "Factors affecting distribution of blackbuck (*Antilope cervicapra*) in India and Nepal" 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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Recommendation

This is to recommend that the dissertation entitled "Factors affecting distribution of blackbuck (*Antilope cervicapra*) in India and Nepal" has been carried out by Sadhana Shrestha for the partial fulfilment of Master's Degree of Science in Zoology with special paper Ecology & Environment. This is her original work and has been carried out under my supervision. To the best of my knowledge, this dissertation work has not been submitted for any other degree in any institutions.

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Certificate of acceptance

This dissertation work submitted by Sadhana Shrestha entitled "Factors affecting distribution of blackbuck (*Antilope cervicapra*) in India and Nepal" has been accepted as a partial fulfilment for the requirements of Master's Degree of Science in Zoology with special paper Ecology and Environment.

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Abstract

Blackbuck (*Antilope cervicapra*) is the native species to the four countries (Nepal, India, Pakistan and Bangladesh) of Indian subcontinent. It has gone regionally extinct from Bangladesh and Pakistan. It is important to understand the response of species towards its environment to ensure proper management of the species. This study aims to understand the influence of different environmental variables like bioclimatic, landcover and anthropogenic disturbance factors to the blackbuck. The occurrence of blackbuck within India and Nepal were considered for the study. So, the data for Nepal were collected through direct observation and for India were obtained from GBIF. Heatmap was prepared to assess the density of occurrence of blackbuck. The blackbucks were found widely distributed in India within the states like Rajasthan, Gujarat, Tamil Nadu, Karnataka, etc. Blackbuck were mostly distributed in the Rajasthan and Gujarat of India. The distribution was found to be very less in Nepal. It was only concentrated to the protected area of the western Tarai. Generalized Linear Model (GLM) was used to analyze the influence of the different environmental factors. The factors such as grassland and cropland have positive influence on the presence of blackbucks, while variables like elevation and precipitation measures have varying effects on their likelihood of occurrence in a given area. It was found that blackbuck prefers the open habitats with abundant food resources and tends to avoid the road. So, it is important to consider environmental factors for the effective management of the blackbuck. Moreover, potential suitable habitats should be studied in Nepal for the translocation of the blackbuck.

शोध सार

कृष्णसार (*Antilope cervicapra*) भारतीय उपमहाद्वीपका चार देशहरू (नेपाल, भारत, पाकिस्तान र बंगलादेश) मा पाइने मूल प्रजाति हो । यो बंगलादेश र पाकिस्तानबाट क्षेत्रीय रूपमा लोप भएको छ । प्रजातिहरूको उचित व्यवस्थापन सुनिश्चित गर्न यसको वातावरणप्रति प्रजातिहरूको प्रतिक्रिया बुझ्न महत्त्वपूर्ण छ । यस अध्ययनले कृष्णसारमा जैविक जलवायु, ल्यान्डकभर र मानवीय गतिविधि कारकहरू जस्ता विभिन्न वातावरणीय कारकहरूको प्रभावलाई बुझ्ने लक्ष्य राखेको छ । अध्ययनका लागि भारत र नेपाल भित्र कृष्णसारको घटनालाई विचार गरियो । तसर्थ, नेपालका लागि डाटा प्रत्यक्ष अवलोकनबाट सङ्कलन गरिएको थियो र भारतका लागि GBIF बाट प्राप्त गरिएको थियो । कृष्णसारको उपस्थितिको घनत्व मूल्याङ्कन गर्नको लागि Heatmap तयार गरिएको थियो । कृष्णसार भारतमा राजस्थान, गुजरात, तमिलनाडु, कर्नाटक आदि राज्यहरूमा व्यापक रूपमा उपस्थिति रहेको पाइन्छ । कृष्णसार प्रायः भारतको राजस्थान र गुजरातमा वितरण गरिएको थियो । नेपालमा वितरण निकै कम भएको पाइएको छ । यो पश्चिम तराईको संरक्षित क्षेत्रमा मात्र केन्द्रित थियो । विभिन्न वातावरणीय कारकहरूको प्रभावको विश्लेषण गर्न Generalized Linear Model (GLM) प्रयोग गरिएको थियो । घाँसे मैदान र बाली जमिन जस्ता कारकहरूले कृष्णसारको उपस्थितिमा सकारात्मक प्रभाव पार्छ, जबकि उचाइ र वर्षा उपायहरू जस्ता चरहरूले दिइएको क्षेत्रमा तिनीहरूको सम्भावनामा फरक प्रभाव पार्छ । कृष्णसारले प्रशस्त खाद्यान्न स्रोत भएको खुला बासस्थानलाई रुचाउने पत्ता लागेको थियो । त्यसैले, कृष्णसारको प्रभावकारी व्यवस्थापनको लागि वातावरणीय कारकहरूलाई विचार गर्न महत्त्वपूर्ण छ । साथै, कृष्णसारको स्थानान्तरणका लागि नेपालमा सम्भावित उपयुक्त बासस्थानको अध्ययन गरिनुपर्छ ।

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List of abbreviations

Abbreviated form	Details of abbreviation
GBIF	Global Biodiversity Information Facility
GLM	Generalized Linear Model
KrCA	Krishnasaar Conservation Area
ShNP	Shuklaphanta National Park

1. Introduction

1.1 Background

Blackbuck (*Antilope cervicapra*) was found throughout the Indian sub-continent in the past but it is now regionally extinct from the Bangladesh and Pakistan (IUCN SSC Antelope Specialist Group, 2017). This was a common species in the Indian subcontinent until 19th century but has faced serious decline in its population due to anthropogenic pressure, habitat loss, predation pressure, hunting etc. (Daniels & Arivazhagan, 2008; Nagarajan et al., 2016). The habitat preference for this species are open areas like grassland, riverbanks, croplands, pasture lands, scrubland and semi-desert habitat (IUCN, 2017; Chandel et al., 2022; Jha & Isvaran, 2022). These species occupy small area of 2 to 3 hectares with overlapping range of 3.5 to 13.5 km^2 (Bohra et al., 1992 ; Long, 2003). Blackbucks are mostly present in the protected areas within India, Pakistan and Nepal (Tahir, 2022).

Blackbuck's distribution is limited to western Tarai of Nepal (DNPWC, 2017). It is the protected species under National Park and Wildlife Conservation Act 1973. The distribution of blackbuck was restricted to Blackbuck Conservation Area and expanded its population with successful translocation to Hirapur Phanta of Shuklaphanta National Park (KrCA, 2017). Blackbucks are widely distributed in different states of India like Rajasthan, Gujarat, Tamil Nadu, Punjab, etc. (Saran & Meena, 2018). It is more abundant in Rajasthan with its distribution in 19 districts of Rajasthan (Rahmani & Sankaran, 1991a). It is also the protected species under Schedule I of the Indian Wildlife (Protection) Act, 1972. The distribution of blackbucks is also associated with availability of water as they require water on daily basis (Meena & Jaipal, 2020; Tahir, 2022). Blackbucks are ecologically important species as they support the predator species like tiger and maintain the grassland ecosystem (Kral et al., 2017). Blackbucks are at the risk of genetic loss due to small population (Amin et al., 2018). Although there has been efforts for the conservation of blackbucks increasing human population, shrinkage of suitable habitat, urbanization, disease, hunting, etc. has created the pressure on population of blackbucks (Khanal & Chalise, 2011; Meena et al., 2017; Tahir, 2022).

The availability of food resources is also associated with the distribution of the species. Blackbucks shows grazing shifts according to the availability of food resources from grassland to saline habitat (Jhala, 1997). Climatic conditions have impact on the population demography and dynamics of ungulates by affecting the plant productivity or by forcing

behavioral restraints (Sæther, 1997;Martínez-jauregui et al., 2009). Precipitation can affect the distribution of species through direct impact on their physiology and behavior and indirectly through plant-mediated effects and interaction among the species (Deguines et al., 2017). The presence of road can shrink their habitat by acting as barrier and affect their behavior as well (Leblond et al., 2013). This causes influence in distribution pattern of herbivore in some ecosystems (Fahrig & Rytwinski, 2009; Taylor & Surveys, 2015).

The distribution of blackbuck is influenced by biotic and abiotic factors like climate, habitat structure, anthropogenic factors, competition, etc. (Kupika et al., 2018; Verberk, 2012). Habitats have great influence on the demography, breeding biology and behavior of the blackbucks (Jhala & Isvaran, 2016). It is essential to understand and quantify the functional relationship between species and environment including climatic variables to assess distribution of the species (Guisan & Zimmermann, 2000; Luo et al., 2015; Malakoutikhah et al., 2020).

1.2 Statement of problem

Blackbuck is native species to Indian subcontinent. It is only present in India and Nepal in current situation. However, the distribution of blackbuck populations across their range is increasingly influenced by various environmental and anthropogenic factors. Despite being legally protected and inhabiting numerous conservation areas, blackbuck populations continue to face challenges that threaten their survival and distribution. The loss of native species alters the ecosystem of that place (Hooper et al., 2012). The endemic species with small range are at high risk due to climate change (Morueta-Holme et al., 2010). Blackbuck needs more attention as it is endemic to Indian subcontinent. Species distribution is not limited to climatic variables only, other essential variables like land cover type, human influence, etc., should be incorporated for better understanding of species distribution (Brook et al., 2008). These variables potentially limit suitable habitats and affect the availability of resources necessary for blackbuck survival. So, this makes it necessary to understand the relationship between the factors and the distribution of the blackbucks for the effective management and conservation plans to safeguard their future and their ecosystem.

1.3 Objectives

1.3.1 General Objectives

The main objective of this study was to understand the factors affecting the distribution of blackbuck in India and Nepal.

1.3.2 Specific Objectives

- To map the distribution of blackbuck in India and Nepal.
- To examine the factors influencing on the distribution of blackbuck in India and Nepal.

1.4 Significance of the study

This study determines the factors affecting the distribution of the blackbucks by incorporating bioclimatic variables, landcover variables and anthropogenic variables. Despite several studies on blackbucks regarding its population status, conservation status, parasitic infection, etc., there has been minimal studies on the impacts of different variables on its distribution. This study will find the contributing factor and its influence on the distribution of blackbuck. The understanding of the response of blackbuck towards these variables will be of significant value in directing the conservation of the species. This study includes the bioclimatic variables, which plays crucial role in the distribution of the species and helps to interpret the impact of climate change on the blackbuck. The findings can be applicable in predicting the distribution pattern of blackbuck with connection to climate change scenario together with anthropogenic activities. This study can be contributing towards finding the suitable habitats for translocation of blackbuck in Nepal. Moreover, this study helps to understand the interaction of species with the environmental variables which is crucial for maintaining the healthy ecosystem (Malmstrom, 2010).

2. Literature review

2.1 Distribution of blackbuck

Savanna environment supports the high diversity and distribution of the antelope species (Du Toit & Cumming, 1999). Blackbuck was once found everywhere in the Indian subcontinent region (Ranjitsinh, 1989). Though they are distributed in wide range of habitat, their densities are found to be more in semi-arid grasslands (Jarman & Smith, 1974). They are mostly found in the protected areas of India and Nepal (Choudhary & Chisty, 2022). The blackbucks are present in protected areas namely Krishnasaar Conservation Area and Hirapur Phanta of Shuklaphanta National Park in Nepal (DNPWC, 2023). The distribution of blackbuck in Lalpur Jheel of Haryana was found to be clumped with group size ranging from 1 to 58 individuals (Rai & Jyoti, 2019). The population of blackbuck in the village Badopal was fragmented and distributed in the isolated patches (Delu et al., 2024). The study conducted in Nahar Wildlife Sanctuary for habitat suitability analysis found the shrublands that are far from human settlement to be suitable areas for blackbucks (Chandel et al., 2022). Moreover, cultural beliefs of Vishnoi community towards blackbuck as sacred animal also has impacted the distribution of blackbucks with more number of these species around them (Rahmani & Sankaran, 1991b). The distribution blackbuck is more in Rajasthan and Gujarat because it is related with religious sentiments of the people (Mamatha & Hosetti, 2018). The dependence of blackbuck in palatable grassland increases its distribution in the area of Rajasthan with better pasture (Rahmani & Sankaran, 1991a).

The study conducted by Arockianathan and Balasundaram (2018) recorded a total of 1,112 animal sightings within the 14.87 square kilometers of the Ranebennur Blackbuck Sanctuary, located in Ranebennur Taluk of Haveri District, Karnataka. Among these sightings, there were 203 adult males, 657 adult females, 126 young males, and 126 young females. The research also noted an increase in the number of blackbucks observed from June to January, likely due to the rainy and winter seasons, which provided abundant food and favorable habitat conditions. Conversely, a gradual decline in blackbuck density was observed from February to May, attributed to the scarcity of food and water during the hotter months, leading to fewer animal sightings. Mohammed et al. (2016) investigated crop damage caused by blackbucks in and around the Chitta Reserve Forest in Bidar, Karnataka. The study found that blackbucks frequently raided agricultural fields, causing

extensive damage. Sugarcane, pigeon pea, and vegetables were the most affected crops, especially during the summer months. As a result, farmers in the area faced significant losses of their cash crops. Debata (2017) conducted a year-long study, from October 2012 to October 2013, to estimate the population size and age structure of blackbucks in an unprotected area of 61.21 km² in Odisha. The study documented a total of 7,134 blackbucks across 366 herds, with herd sizes ranging from a single individual to the largest herd consisting of 51 animals. The average herd size was 19.49±0.03 (SE), varying from 13.34±0.06 in the summer to 31.86±0.07 during the monsoon. The sex ratio was skewed towards females at a ratio of 3:1. A significant population of blackbucks was found outside the protected area. Khanal (2006) studied the population status of blackbucks in Khairapur, Bardiya, using direct observation methods from April to July 2006. During this period, the total blackbuck population was recorded at 133 individuals, with a crude population density of 25.33 individuals per km² and an ecological density of 75.14 individuals per km² in the core habitat. The average herd size was calculated to be 7.64 individuals per herd, with a male-to-female sex ratio of 1:1.29.

2.2 Factors affecting the distribution of blackbuck

Ungulates use various physiological, morphological and behavioral mechanism to adapt in the arid and semi-arid condition either by avoiding or tolerating the environmental conditions (Cain et al., 2006). The precipitation received during the dry season had more influence on the population dynamics of ungulates in Kruger National Park of Africa as compared to the precipitation received in the wet season (Ogutu & Owen-Smith, 2003). Blackbucks were found to have access to higher quantity and quality of forage during the monsoon, summer and early autumn which are the periods of maximum grass growth as per the study conducted in semi-arid region of western Haryana (Delu et al., 2021). The probability of occurrence of the ungulates near the roads decreases with increase in the traffic volume in the highways of Central Arizona, USA (Gagnon et al., 1985). The herd size is also affected by the habitat openness as it is more in grassland and decreases with dense vegetation (Lagory, 1986). It is necessary to maintain the grassland habitats to support the population of blackbuck (Sathishkumar et al., 2023).

Blackbuck are gregarious in nature and their size of groups are impacted by availability of food resources in their habitat (Iqbal & Ilyas, 2022). This study done in Blackbuck Conservatory Center of Laigarh found the largest group in the cropfield due to the abundant availability of food and the group size was lowest in *Prosopis* patch due to least food.

Bharucha and Asher (1993) observed that the herd size and structure of blackbucks are constantly changing. They noted that the activity patterns of these ungulates are influenced by factors such as age, sex, pasture availability, and climatic conditions. They also found that in protected areas where blackbuck populations are increasing, the animals become more reliant on adjacent cropland, leading to heightened man-animal conflict due to significant localized crop damage. They suggested that blackbuck habitat management should focus on promoting smaller, interconnected populations rather than single, fragmented, high-density groups. The distribution of blackbuck in Thar desert was restricted to the areas with availability of surface water throughout the year (Rahmani & Sankaran, 1991a). The blackbuck are also in conflict with humans in Sorsan region of Rajasthan due to crop damage by blackbucks and overlapping grazing with the livestock (Meena et al., 2017). Kafle (1998) also investigated the conflict between blackbucks and the local residents in Khairapur village, discovering that those living within a 1 km radius experienced the greatest losses. According to 91% of respondents, blackbucks completely destroyed their pulse crops. The crop raiding was more during the summer season due to less availability of the food (Meena et al., 2020). The study conducted in protected areas of Tamil Nadu found the positive relation of open habitat and grass biomass to the density distribution off the blackbuck (Arandhara et al., 2021). The human disturbance was also found to be the factor for group size variation (Iqbal & Ilyas, 2022). Blackbucks distribution were found to be restricted due to the presence of vehicular road and invasive plant species *Prosopis juliflora* which created unsuitable habitat for it (Chandel et al., 2022). The sighting was also found to be affected due to fragmentation of habitat through road construction vehicle movement, encroachment by cattle and increased population of feral dogs in Haryana (Rai & Jyoti, 2019). Delu et al. (2024) studied the seasonal herd pattern of blackbuck in semi-arid region of western Haryana for a year, revealing the species instinct, climatic circumstances and food and habitat availability as a reason behind the seasonal fluctuation of herd pattern. The habitat structure has direct impact on the behavior, group dynamics and breeding biology of the species (Jhala & Isvaran, 2016). According to the study done in KrCA of Nepal, it was found that habitat use by blackbuck is influenced by both ecological and anthropogenic factors (Jha & Isvaran, 2022). Pattnaik (2021) identified the density of blackbuck was driven by the presence of people and cattle. It was predicted that rainfall and temperature may both affect the feeding of blackbuck by the quality and quantity of available vegetation (B.K & Awasthi, 2018).

The above literature review concludes that most of the study on the blackbucks are based on India. The distribution of blackbuck is found to be abundant in India in comparison to the Nepal. The population of blackbuck is very few as well as present only in the patches of western Tarai. The study is also limited to the population status, habitat use and conflict due to crop raiding by blackbuck. There are few studies on the factors that are influencing the distribution of the blackbuck but it is concentrated towards the small areas. Although blackbucks are widely distributed in India, it is confined to isolated pockets of western Tarai in Nepal. There are many aspects like physiology, genetics, ecology, etc. to be explored in the context of blackbuck. This study bridges the gap by understanding the factors that determine the distribution of the blackbuck within its native range. It also helps in understanding the response of blackbuck towards the climatic variable, human disturbances and land use change. Overall, this will help in effective management of this species by considering the influence of the environmental variables on it.

3. Materials and methods

3.1 Study area

The study area consists of two countries: Nepal and India. The Himalayas form a natural boundary to the north and the Indian Ocean towards the south of the Indian subcontinent. This region is recognized as one of the world's biodiversity hotspots, characterized by high species richness and endemism (Myers et al., 2000). It has diverse topography ranging from mountains, plains, plateaus, deserts and coastal areas. The varied topography creates a mosaic of habitats, each with its own unique environmental conditions, further shaping the biodiversity patterns (Rahbek, 2005). The climate is complex and diverse with notable variations in weather pattern across different region (Sperber et al., 2013). India's climate varies significantly, from tropical in the south to temperate and alpine in the Himalayan north (Rengaswamy & M.G., 2008). Nepal's climate ranges from subtropical in the Tarai to alpine in the Himalayas. Nepal reflected unique geographic position, wide altitudinal variations and diverse climatic conditions that result in different physiographic zones including 29% forest area, 10.6% shrub land and degraded forest, 12% grassland, 21% farmland, 2.6% water body, and 7% of uncultivated inclusions (MoFE, 2024) within a short span stretching 885 km from east to west and 193 km north to south (MoFA, 2024). This climatic variation contributes to the country's rich biodiversity. This region harbors rich biodiversity because of its variability in environment (Yadav et al., 2021).

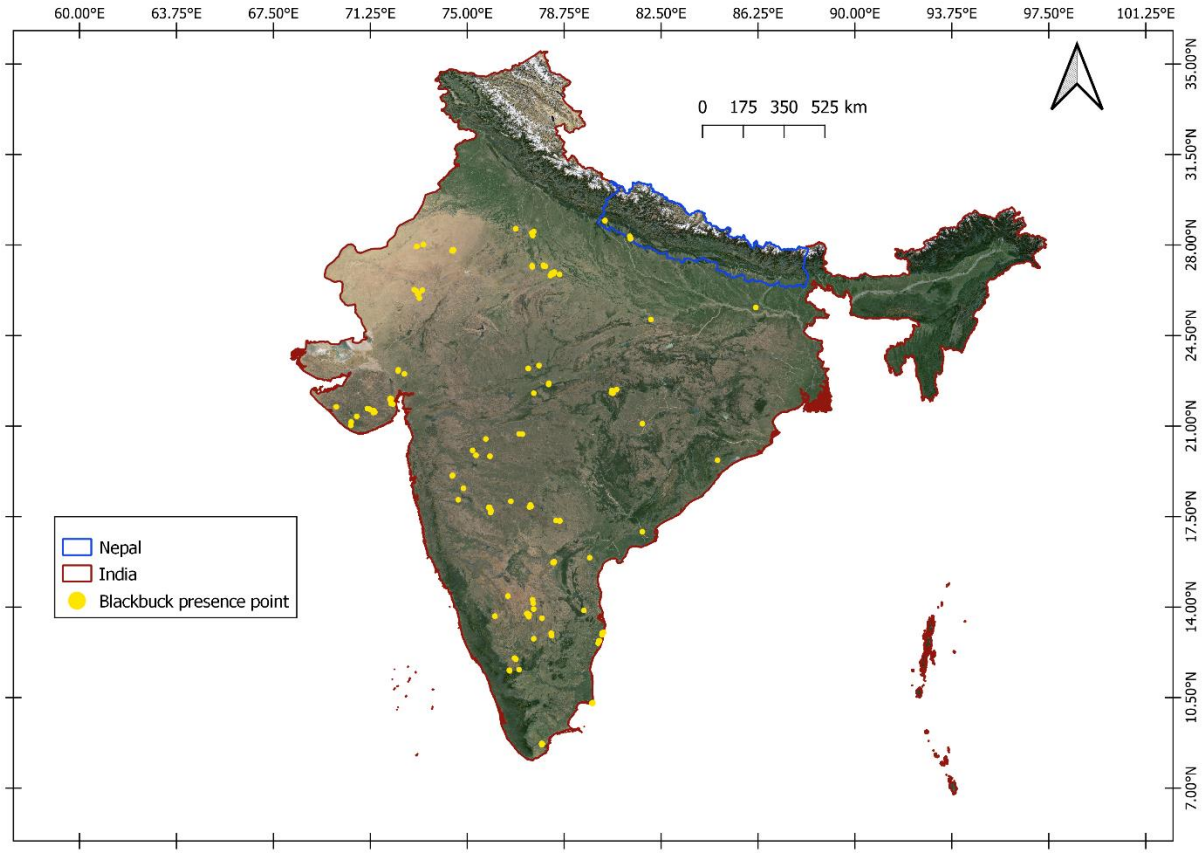

Figure 1. Study area with distribution of blackbuck

3.2 Data collection

3.2.1 Occurrence of blackbuck

The data for the occurrence of blackbucks were obtained through multifaceted approach including field work and online database like Global Biodiversity Information Facility (GBIF) and personnel sources like communication with the resource person of the study area. The field work includes direct observation of the species. It was conducted in Krishnasaar Conservation Area (KrCA) and Shuklaphanta National Park (ShNP). The open grassland within the study area was surveyed with the help of field guide using binocular. Once the animal was detected, the presence point was noted down with the help of GPS and the number of individuals were also counted. In addition the occurrence data were obtained from the GBIF. The occurrence point were taken from the India and Nepal of the last ten years (2014 to 2024). The occurrence points were selected on the basis of availability of photographs of blackbuck. The number of individuals on the given presence point were counted and were considered for the study.

3.2.2 Environmental Parameters

Many studies recognize the importance of combining habitat variables with climatic and anthropogenic factors to generate ecologically more significant results (Cervellini et al., 2021; Katuwal et al., 2023; Montalvo et al., 2023). Bioclimatic factors represent annual cycles, seasonal variation, and temperature and precipitation condition that impacts the distribution of species (Hijmans et al., 2005). A total of 19 bioclimatic variables and elevation data were downloaded from Worldclim version 2.1 (https://www.worldclim.org/) (Fick & Hijmans, 2017) at a resolution of 30 arc s (~1 km^2) to understand the distribution of blackbuck. In addition, land use are important factors affecting distribution of wild animals (Gebo et al., 2022). So the global land use and land cover change simulations were downloaded from figshare (https://figshare.com/) based on 1km global land use dataset (Li et al., 2016). All of the variables were in the resolution of 30 arc s (~1 km^2) to match the extent of bioclimatic variables. The distance to road was measured using open street map.

3.3 Statistical analysis

The data collected from the field as well as from secondary sources were entered in the Excel sheet for analysis. All the presence point and their corresponding raster values of variables calculated from QGIS was entered carefully in the spreadsheet. The variables including the distance were calculated through NNjoin plugin of QGIS. The distribution was mapped by using QGIS software. The Kernel Density Estimation feature was used to prepare the heat map on the basis of density of occurrence points. The correlation analysis was used to find the highly correlated variables in the data by using the package corrplot (Wei et al., 2017). The correlation test was done with the threshold of $|r| > 0.7$ (Dormann et al., 2013). The highly correlated variables (Figure 2) were excluded to avoid multicollinearity and overfitting of the data.

The variables obtained after correlation were standardized for further analysis. The predictor variables selected for analysis were Bio 9, Bio 10, Bio 14, Bio 15, Bio 16, Bio 18, grassland, cropland, forest, elevation and distance to road. Generalized Linear Model (GLM) with Poisson family and log link function was used to predict the distribution of the blackbuck on the basis of above variables. The package tidyverse (Wickham, & Henry, 2022), and dplyr (Wickham et al., 2023) was used to arrange the data. The test for overdispersion was done using the package “AER”. Since the data was overdispersed, the

negative binomial regression was used to understand the influence of predictor variables. The models were created using all the possible combinations of predictor variables and ranked according to their corrected AIC values for small sample size (AICc) by using dredge function from MuMIN package (Barton & Barton, 2023). The top sets of N models with $\Delta AICc \leq 4$ were chosen and model averaging was done (Burnham & Anderson, 2002). All analysis were run in the software R 4.3.2 (R Core Team, 2023).

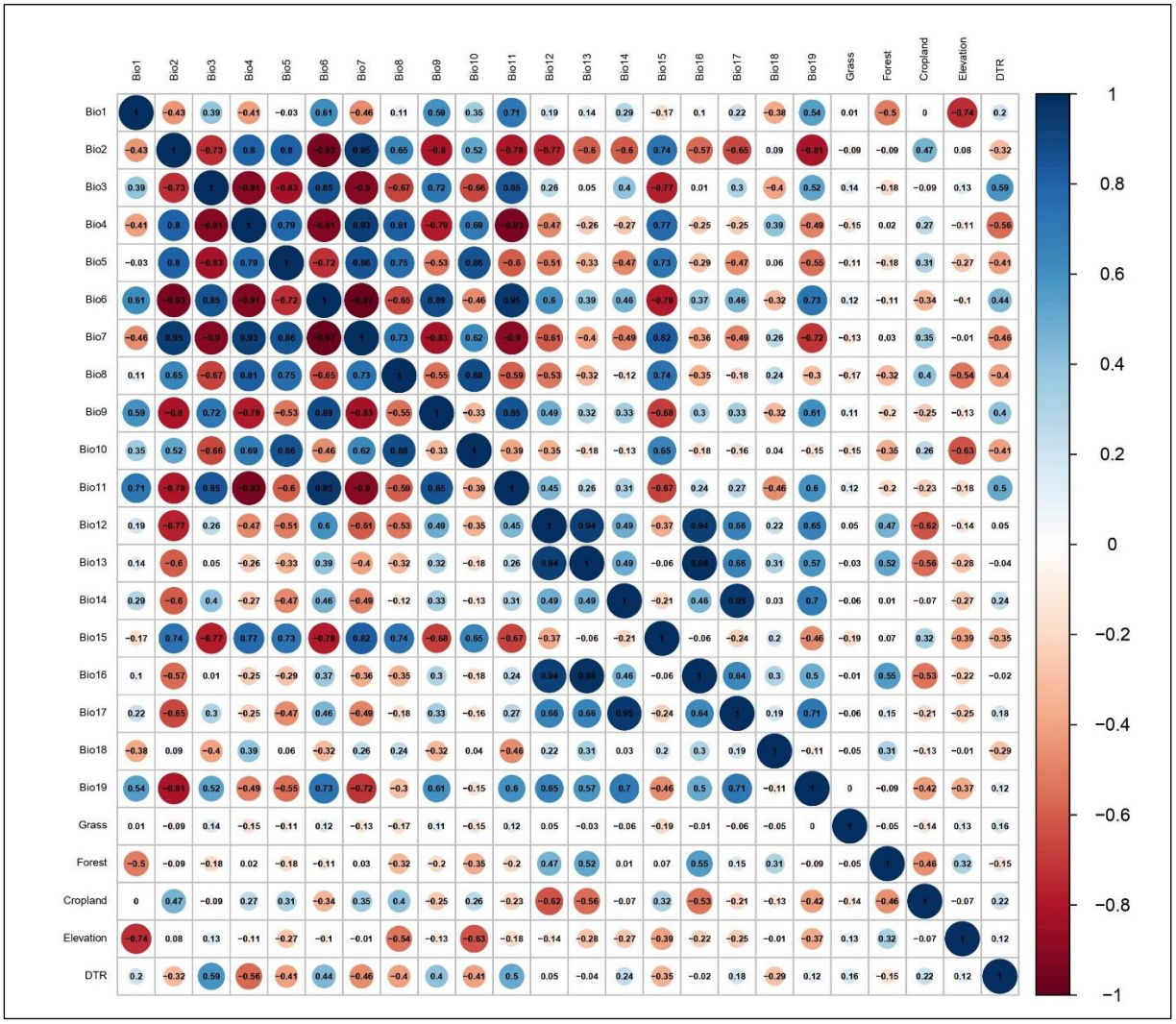

Figure 2. Correlation heat map of predictor variables

4. Results

4.1 Distribution of blackbuck

The distribution of blackbuck was found to be more in the states Rajasthan and Gujarat followed by states Tamilnadu, Andhra Pradesh and Karnataka of the India. Although blackbuck have disappeared from many locations as a result of habitat degradation from hunting and farming practices, they are reappearing in several South Asian protected areas as well as Vishnoi-dominated areas in Rajasthan and Haryana, India (Jyoti & Rai, 2021). Blackbucks are conserved by protected area like Velavadar National Park, Great Indian Bustard Wildlife Sanctuary, Point Calimere Wildlife Sanctuary, Guda-Vishnonian and Taal Chhapar Blackbuck Sanctuary etc. in India. Blackbuck numbers decreased over the 20th century as a result of overhunting (Mallon & Kingswood 2001). The northern region of India including states like Himachal Pradesh, Ladakh, Arunachal Pradesh, Assam etc. did not have any occurrence of blackbuck. In Nepal, the distribution of blackbuck was concentrated towards the western Tarai region only. It is present only in the protected area of Nepal which includes KrCA and ShNP.

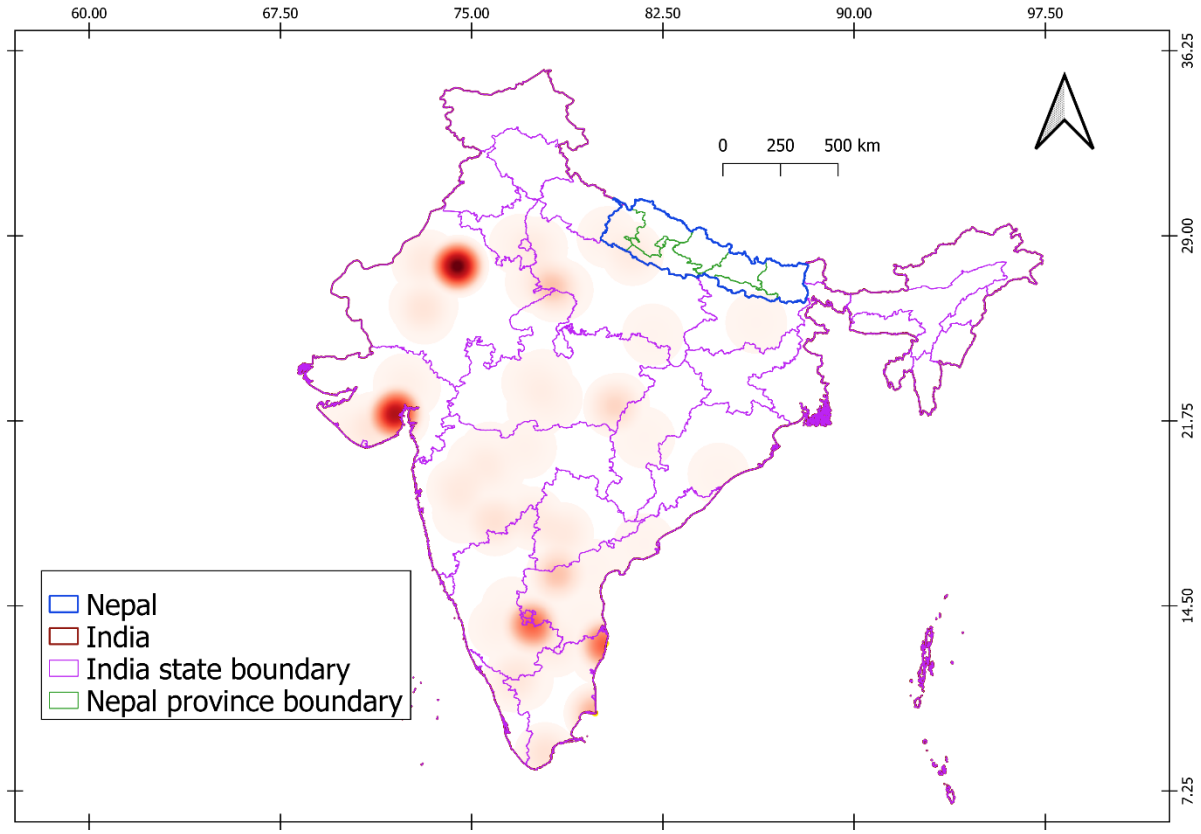

Figure 3. Heat map showing the density of occurrence of blackbuck in India and Nepal (Dark color represents high density while light color represents low density)

4.2 Factors affecting the distribution of blackbuck

The distribution of blackbuck was influenced by grassland, cropland, elevation and precipitation of the driest month (Table 1). The landcover with grass and cropland have positive influence on the distribution of blackbuck. The elevation and bioclimatic variable, precipitation of driest month (Bio 14) shows negative association with the distribution of blackbucks.

Table 1. Model averaged parameters and their lower confidence interval (LCI) and upper confidence intervals (UCI) to describe the factors affecting the distribution of blackbuck in India and Nepal. Variables such as blackbuck abundance as response variable and Bio 9, Bio 10, Bio 14, Bio 15, Bio 16, Bio 18, Cropland, Distance to road, Elevation, Forest and Grassland are predictive variables. Significant effects are in bold.

Parameters	**Estimate**	**SE**	**LCI**	**UCI**	**Z- value**	**p- value**
(Intercept)	1.185	0.050	1.085	1.285	23.241	**<0.001**
Bio 9 (°C)	0.114	0.105	-0.093	0.321	1.077	0.281
Bio 10 (°C)	0.093	0.100	-0.103	0.290	0.933	0.350
Bio 14 (mm)	-0.186	0.067	-0.318	-0.054	2.772	**0.005**
Bio 15 (%)	0.181	0.109	-0.034	0.396	1.650	0.098
Bio 16 (mm)	-0.093	0.086	-0.193	0.022	1.079	0.280
Bio 18 (mm)	0.033	0.061	-0.087	0.153	0.541	0.588
Cropland (%)	0.219	0.074	0.072	0.365	2.931	**0.003**
Distance to road(m)	0.105	0.066	-0.026	0. 236	1.569	0.116
Elevation (m)	-0.165	0.077	-0.317	-0.013	2.129	**0.033**
Forest (%)	0.002	0.086	-0.168	0.172	0.024	0.981
Grass (%)	0.106	0.051	0.006	0.207	2.084	**0.037**

The precipitation of driest month (Bio 14) has negative influence on the abundance of blackbuck (Figure 4). The blackbuck abundance is more in the area with low precipitation during driest month and it keeps decreasing with the increase in the precipitation of driest month.

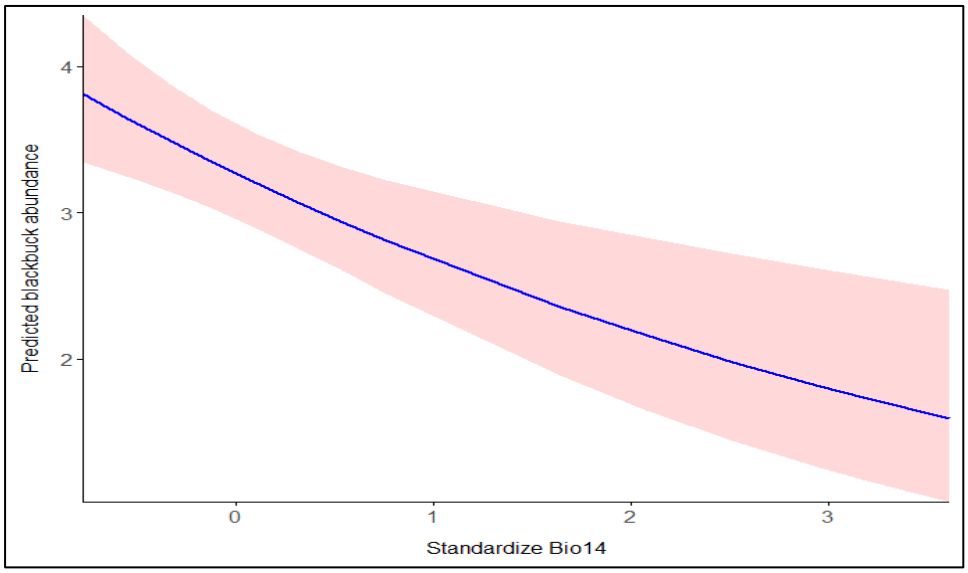

Figure 4. Effect of Precipitation of driest month (Bio 14) on the abundance of blackbuck

The cropland have positive influence on the abundance of blackbuck (Figure 5). The blackbuck abundance is more in the area with high cropland cover while it is low in the area with less cropland cover.

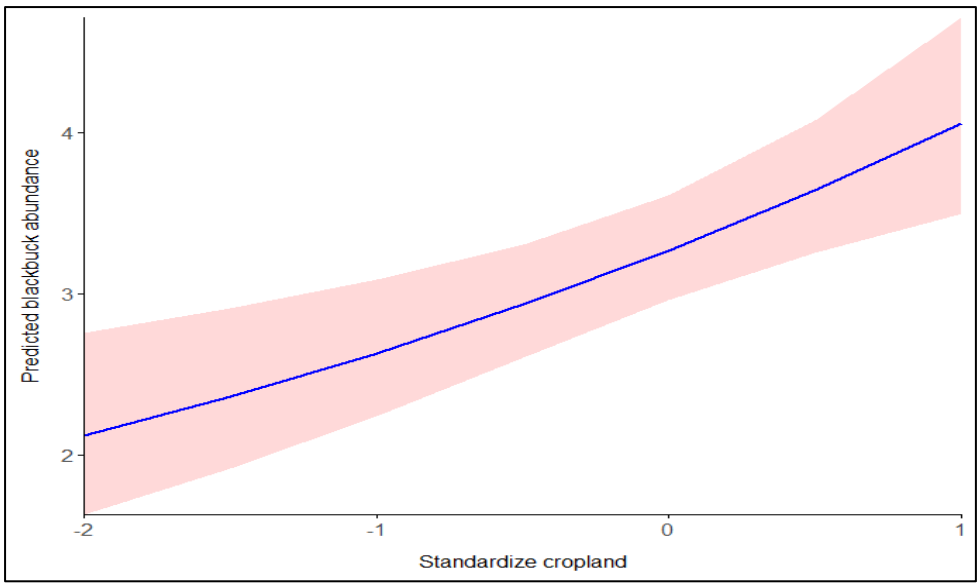

Figure 5. Effect of cropland cover on abundance of blackbuck

The elevation has negative influence on the abundance of blackbuck (Figure 6). The blackbuck abundance is more in the area with low elevation and it keeps decreasing with the increase in the elevation.

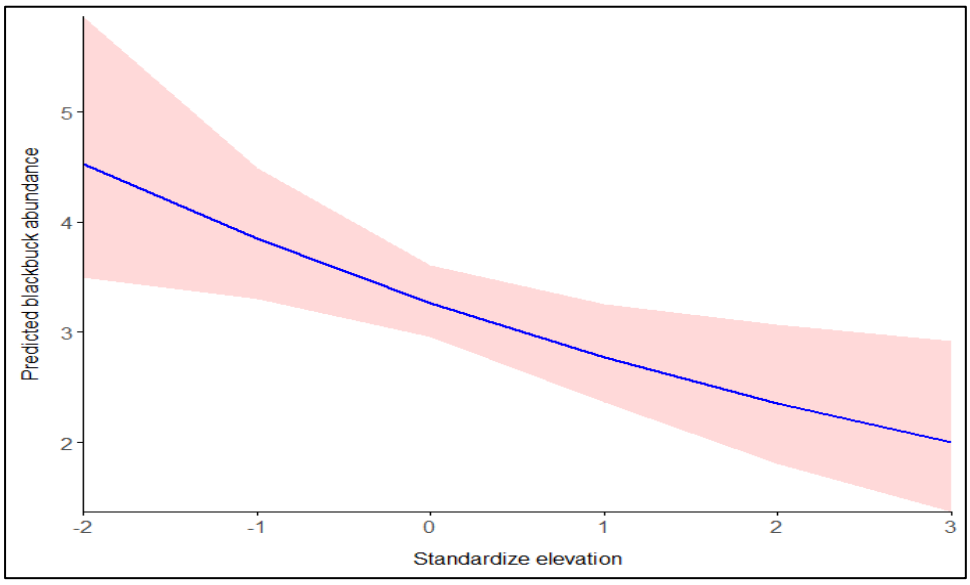

Figure 6. Effect of elevation on abundance of blackbuck

The grassland have positive influence on the abundance of blackbuck (Figure 5). The blackbuck abundance is more in the area with high grassland cover while it is low in the area with less grassland cover.

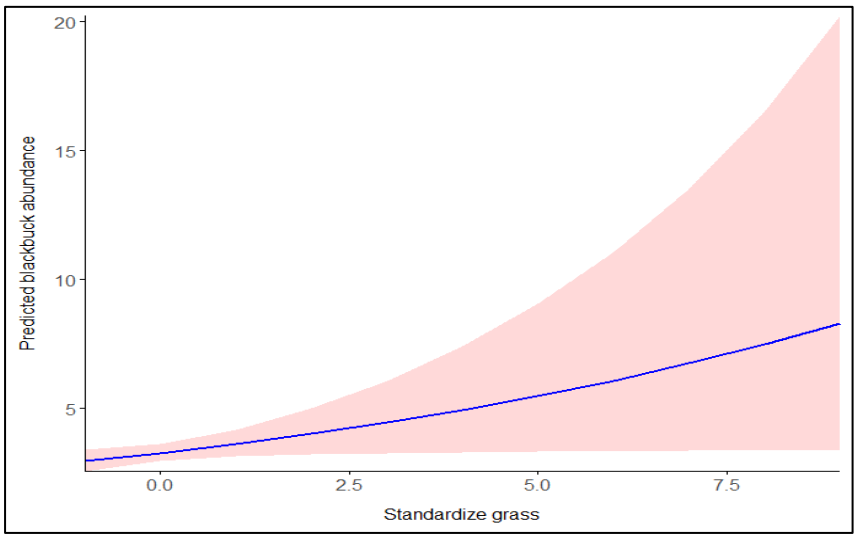

Figure 7. Effect of grassland cover on abundance of blackbuck

5. Discussion

5.1 Distribution of blackbuck

Blackbucks are highly specialize antelopes adapted to the short grass semi-arid environment (Jhala & Isvaran, 2016). The blackbuck is found in 15 states across India, including 19 districts in Rajasthan, where over 30,000 blackbucks were observed in 2016 (Rahmani 1991; Srinivasulu & Nagulu 2002; Sharma et al. 2003; Saran and Meena 2018). Blackbucks were found in Bahawalpur and Fort Abbas, located in the northern region of the Cholistan desert in Punjab, near the border with India (Roberts, 1977). Blackbuck was also introduced to Texas and Argentina for game purpose and found extant there (IUCN, 2017).

The distribution of blackbuck is profound in Rajasthan and Gujarat, which is notable for its diverse ecosystems, ranging from arid deserts to rich grasslands. Blackbucks are predominantly found in the grasslands and semi-arid regions of Rajasthan (Jarman & Smith, 1974). These areas provide the open terrain that blackbucks prefer, which facilitates their need for space and visibility to avoid predators (Jhala et al., 2008). In many parts of Rajasthan and Gujarat, blackbucks are protected due to their association with the Vishnoi community, which holds them sacred (Mamatha & Hosetti, 2018). This cultural significance has played a crucial role in ensuring their protection and has contributed significantly to their population stability (Rahmani & Sankaran, 1991b). Blackbucks have adapted well to the arid and semi-arid conditions of Rajasthan. Their ability to survive in harsh climates with limited water availability and their grazing habits on native grasses have allowed them to thrive.

In Nepal, the distribution of blackbuck is found towards the western lowland only. Dinerstein (1975) and Wegge and Wilson (1976) also has reported the existence of two small remnant populations of blackbucks in the Bardiya and Banke districts of the Western Tarai in Nepal. In present days, blackbuck population is present in the Krishnasaar Conservation Area of Bardiya and Hirapur Phanta of Shuklaphanta National Park. The blackbuck population were translocated to Hirapur Phanta from the various places like Nepalgunj mini zoo and Central Zoo (DNPWC, 2023). The different locations of Shuklaphanta National Park was identified as potential translocation sites by Khanal (2002) with the help of different survey technique like field survey, direct observation and questionnaire methods. Kunwar et al. (2015) investigated the distribution probability of the

species and forecasted a limited number of suitable habitats, primarily located in the Tarai region of Nepal. The most suitable habitats were identified mainly in and around the Blackbuck Conservation Area, near Bansgadi in Bardiya, and extending southward towards the Indian border.

5.2 Factors affecting distribution of blackbuck

The positive influence of grassland (Figure 7) indicates that areas classified as grasslands are more likely to have blackbuck compared to other land cover types. Grasslands are preferred by the blackbuck for foraging (Jha & Isvaran, 2022). This dietary choice is due to the better quality which includes soft-texture, digestibility, palatability and higher nutritional value (Sathishkumar et al., 2023). The average intake of grasses in the summer season was high than during the winter season (Bhandari, 1994). The blackbuck primarily prefers grassland for grazing which allow them to escape from predators also. Moreover, blackbucks mostly prefers the open habitat which justifies this relationship (Gehlot, 2006). This finding is similar to the study in Central-eastern India which outlines the distribution of blackbuck more in the area dominated by herbs (Pattnaik, 2021). Schaller (1967) reported that the primary diet of blackbucks in Kanha National Park consists of short grasses, such as *Chrysopogon, Paspalum,* and *Sporobolus.* He observed that female blackbucks graze more frequently than males, aligning with Nair (1975) finding that males spend more time lying down than females.

The cropland shows the great significance for the distribution of blackbuck (Figure 5). The cropland provides the blackbuck with high quality forage due to the shortage of food resulting from habitat fragmentation (Meena & Jaipal, 2020; Jha & Isvaran, 2022). The blackbucks used cropland as their foraging ground when there was scarcity of food in their natural habitat (Delu et al., 2021). It was also found that average intake of crops was higher in winter than during the summer (Bhandari, 1994). It also has created conflict between local people and blackbuck in Khairapur as the pulses were completely destroyed by the blackbuck with maximum loss to the people living within 1km distance (Kafle, 1998). It is also considered as the crop pest mainly feeding on the young shoots of cereal and pulses (Chauhan & Singh, 1990). It might be due to open habitat and lower predation pressure in the cropland (Iqbal & Ilyas, 2022). This finding aligns with the findings of Arandhara et al. (2021), which reported the positive association of blackbuck distribution with the habitat openness.

The negative association for elevation (Figure 6) suggests that as elevation increases, the likelihood of blackbuck presence decreases substantially. Blackbucks are primarily found in grasslands and open plains, preferring lower elevations where suitable habitats such as grasslands and shrublands are more abundant. As elevation increases, temperatures generally decrease, which can limit the survival of species adapted to warmer desert climates (Körner, 2007). Higher elevations may not provide the ideal habitat conditions required by blackbucks, leading to a decrease in their presence as elevation increases.

The influence of climatic variable on herbivore is mediated through quality and quantity of plants (Mysterud et al., 2001, 2008). The negative coefficient for precipitation of driest month (Bio 14) suggests that as precipitation in the driest month increases (Figure 4) the presence of blackbuck decreases. This implies that an increase in precipitation during the driest month leads to a decrease in the presence of blackbuck. This could indicate that blackbuck prefer drier conditions or have adapted to survive with lower levels of precipitation. The preference of blackbuck towards the drier condition might be due to its association with semi-arid habitat (Bohra et al., 1992; Jhala et al., 1992). Blackbuck adapt to the arid environment by producing highly concentrated alkaline urine and dry feces (Jhala & Isvaran, 2016). Contrary to this finding, it was found that blackbucks did not prefer the area with unavailability of surface water (Rahmani & Sankaran, 1991a). Despite of not being totally independent of drinking water, they can adapt their physiology during the shortage of water for many days (Jhala et al., 1992).

6. Conclusions and recommendations

6.1. Conclusions

This study maps the distribution of blackbuck more in the area with semi-arid environment like Rajasthan and Gujarat. It was found abundantly distributed in the India. It is present in the most of the protected area of the India. The distribution of blackbuck is related with the religious sentiment of the people also. It has been protected by Vishnoi community as a sacred animal, so they are found to be distributed more in the area of Vishnoi community. The distribution is limited in Nepal as compared to India. It is found only in the Krishnasaar Conservation Area and Hirapur Phanta of Shuklaphanta National Park. It was only present in the Krishnasaar Conservation Area in the beginning and has been translocated to Hirapur Phanta of Shuklaphanta National Park. Since, the distribution of blackbuck in Nepal is confined in the boundary of protected areas only, it is necessary to establish this northern population of the blackbuck. It also concludes that the distribution of the blackbuck is influenced by the cropland, grassland, precipitation and elevation. Moreover, it is positively linked with the availability of the food and its suitable habitat. So, it is necessary to understand the influence of all these factors for the conservation and management of the species.

6.2. Recommendations

Despite of abundant distribution in India, the distribution is limited to isolated pockets in Nepal. Thus, it is recommended to study for potential suitable habitat for translocation of blackbuck within Nepal. This study recognizes the importance of climatic variables and landcover variables for the distribution of the blackbuck. It is recommended to consider the grassland management for the effective conservation and management of the blackbuck. Since, the crop raiding behavior of blackbuck might cause the conflict, it is necessary to study about the ways to mitigate it for sustainable coexistence.

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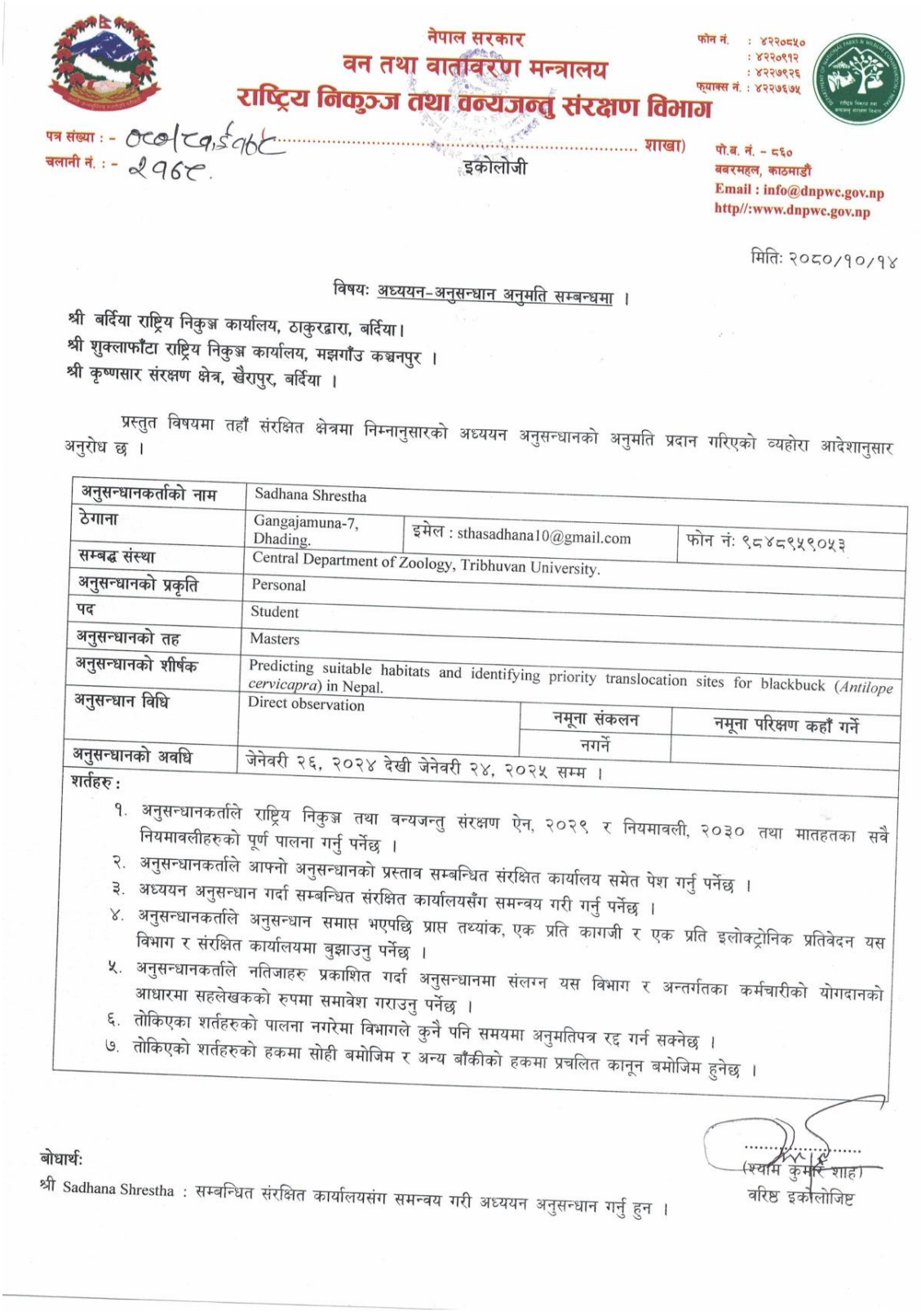
Appendices

Appendix 1. Research permission letters



नेपाल सरकार
वन तथा वातावरण मन्त्रालय
राष्ट्रिय निकुञ्ज तथा वन्यजन्तु संरक्षण विभाग

फोन नं. : ४२२०८५०
: ४२२०९१२
: ४२२७९२६
फ्याक्स नं. : ४२२७६७५

पत्र संख्या : - ०८०/८१/२०८८ ..... शाखा)
चलानी नं. : - २१६८ इकोलोजी

पो.ब. नं. - ८६०
बबरमहल, काठमाडौं
Email : info@dnpwc.gov.np
http//:www.dnpwc.gov.np

मितिः २०८०/१०/१४

विषयः अध्ययन–अनुसन्धान अनुमति सम्बन्धमा ।

श्री बर्दिया राष्ट्रिय निकुञ्ज कार्यालय, ठाकुरद्वारा, बर्दिया।
श्री शुक्लाफाँटा राष्ट्रिय निकुञ्ज कार्यालय, मझगाँउ कञ्चनपुर ।
श्री कृष्णसार संरक्षण क्षेत्र, खैरापुर, बर्दिया ।

प्रस्तुत विषयमा तहाँ संरक्षित क्षेत्रमा निम्नानुसारको अध्ययन अनुसन्धानको अनुमति प्रदान गरिएको व्यहोरा आदेशानुसार अनुरोध छ ।

अनुसन्धानकर्ताको नाम	Sadhana Shrestha		
ठेगाना	Gangajamuna-7, Dhading.	इमेल : sthasadhana10@gmail.com	फोन नं: ९८४८९५९०५३
सम्बद्ध संस्था	Central Department of Zoology, Tribhuvan University.		
अनुसन्धानको प्रकृति	Personal		
पद	Student		
अनुसन्धानको तह	Masters		
अनुसन्धानको शीर्षक	Predicting suitable habitats and identifying priority translocation sites for blackbuck (*Antilope cervicapra*) in Nepal.		
अनुसन्धान विधि	Direct observation	नमूना संकलन नगर्ने	नमूना परिक्षण कहाँ गर्ने
अनुसन्धानको अवधि	जेनेवरी २६, २०२४ देखी जेनेवरी २४, २०२५ सम्म ।		

शर्तहरु :

१. अनुसन्धानकर्ताले राष्ट्रिय निकुञ्ज तथा वन्यजन्तु संरक्षण ऐन, २०२९ र नियमावली, २०३० तथा मातहतका सबै नियमावलीहरुको पूर्ण पालना गर्नु पर्नेछ ।
२. अनुसन्धानकर्ताले आफ्नो अनुसन्धानको प्रस्ताव सम्बन्धित संरक्षित कार्यालय समेत पेश गर्नु पर्नेछ ।
३. अध्ययन अनुसन्धान गर्दा सम्बन्धित संरक्षित कार्यालयसँग समन्वय गरी गर्नु पर्नेछ ।
४. अनुसन्धानकर्ताले अनुसन्धान समाप्त भएपछि प्राप्त तथ्यांक, एक प्रति कागजी र एक प्रति इलोक्ट्रोनिक प्रतिवेदन यस विभाग र संरक्षित कार्यालयमा बुझाउनु पर्नेछ ।
५. अनुसन्धानकर्ताले नतिजाहरु प्रकाशित गर्दा अनुसन्धानमा संलग्न यस विभाग र अन्तर्गतका कर्मचारीको योगदानको आधारमा सहलेखकको रुपमा समावेश गराउनु पर्नेछ ।
६. तोकिएका शर्तहरुको पालना नगरेमा विभागले कुनै पनि समयमा अनुमतिपत्र रद्द गर्न सक्नेछ ।
७. तोकिएको शर्तहरुको हकमा सोही बमोजिम र अन्य बाँकीको हकमा प्रचलित कानून बमोजिम हुनेछ ।

(श्याम कुमारि शाह)
वरिष्ठ इकोलोजिष्ट

बोधार्थः
श्री Sadhana Shrestha : सम्बन्धित संरक्षित कार्यालयसंग समन्वय गरी अध्ययन अनुसन्धान गर्नु हुन ।

Appendix 2. Photographs of blackbucks from KrCA

Appendix 3. Photographs of blackbucks from Hirapur Phanta of Shuklaphanta National Park