FACTORS AFFECTING HABITAT SELECTION OF THE ENDANGERED INDIAN PANGOLIN (*MANIS CRASSICAUDATA)* IN RAVINE HABITATS AT THE HIMALAYAN FOOTHILLS, PAKISTAN

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Abstract. As one of the four extant species of Asian pangolins, the Indian Pangolin *Manis crassicaudata* is the only species found in Pakistan that is enlisted endangered due to trafficking and illegal trade. The current study investigated the factors affecting pangolin presence in the ravine habitats of Margalla Hills National Park, Islamabad, Pakistan. Between May and June 2022, we conducted a sign survey based on the line transect method confirming species presence. In addition, 12 passive infrared motion-triggered cameras were also deployed for a total of 132 trap nights with only two captures at a single camera station. Among the 51 signs observed, 32 were burrows. Digging and pug marks were counted as 17 and two, respectively. Most burrows (97%) were categorized as inactive burrows, of which the pangolin used most (78.28%) for feeding. The statistical analysis showed that the nearest settlement does not impact the pangolin presence ($p = 0.209$). Roads were found to have a positive correlation with pangolin presence ($p = 0.018$), yet, agricultural lands were significantly avoided by the Indian pangolin ($p = 0.001$). Our results suggest that the Indian pangolin inhabit areas between forests and agricultural lands yet close to human settlements and roads.
Keywords: *sign survey, Manis crassicaudata, camera traps, Margalla Hills National Park, human settlements*

Introduction

Ecology, fitness and survival of animals depend on the vital process of habitat selection (Resetarits and Binckley, 2009). Habitat selection is a complex behavioral process that allows animals to select the best among existing habitats (Mayor et al., 2009; Mohammadi, 2010). Therefore, investigating habitat selection is crucial to understand abundance and distribution of each species in space and time (Hodara and Busch, 2010). Several factors including both natural and anthropogenic affect habitat selection. (Shilereyo et al., 2021). Thus, habitat selection and insights into the scale and degree of habitat diverseness vary among species (Coppeto et al., 2006). Therefore, understanding the factors affecting habitat selection can provide useful information in managing and conserving threatened species (Hebblewhite and Haydon, 2010).

Small mammals are vital components of ecosystems performing numerous functions like dispersing seeds and fungus, and they are soil aerators (Wilske et al., 2015; Geng et al., 2017; Wang et al., 2017; Stephens and Row, 2020). Simultaneously, they maintain the abundance, distribution and population dynamics of other animal species by being predators of insects and other invertebrates and as prey for several predators (St Clair, 2009; Ojeda and Chazarreta, 2018; Stoessel et al., 2019). Although information on habitats occupied by small mammals is abundant, yet, there is still lack of literature about the factors within a locality that influence species abundance and distribution (Geier, 1980), particularly when it comes to endangered small mammals in un-even habitats (Sponchiado et al., 2012).

The Indian pangolin (*Manis crassicaudata* E'. Geoffroy, 1803) is a medium-sized mammal and is one of the four extant species of pangolin in Asia (Karawita et al., 2018). The Indian pangolin is primarily myrmecophagous—having exceptional behavioral and anatomical peculiarities to prey on ants and termites (Yang et al., 2007). Of all Asian pangolin species, the Indian pangolin is perhaps under-researched and is the only one in Pakistan (Mahmood et al., 2014). Indian pangolin occurs throughout Pakistan except in the northern parts of Khyber Pkahtunkhwa (KP) and Gilgit-Baltistan Province. Rising alarms over the population's drastic declines due to poaching and trafficking have stressed the need for more intensive conservation actions for Indian pangolin (Challender., 2011). Due to past and expected population declines, the Indian pangolin is listed as 'Endangered' globally and in Pakistan (Shiekh and Molur, 2004; Baillie et al., 2014).

The Indian pangolin inhabits a wide range of habitats in its geographical range, including plateaus, forests, plains, agricultural lands etc. (Roberts, 1997; Karawita et al., 2018). This species is adjustable to altered habitats—akin to the availability of food resources and zero poaching (Waseem et al., 2020). However, major proportions of the Indian pangolin range in Pakistan are overlapped by high human population densities, coupled with an upsurge in agricultural practices (irrigation and use of pesticides)—leading to the deterioration and loss of habitats (Zoological Society of India, 2002). Based on the evidence mentioned above, we presume that the Indian pangolin may tend to avoid anthropogenic factors. Therefore, the current study was designed to investigate the factors that affect the Indian pangolin habitat selection in a ravine habitat and suggest recommendations for better preservation of these habitats.

Material and methods

Study area

The present study was conducted in Margalla Hills National Park (MHNP), located between 33° 43' N and 72° 55' E at the foot of the Himalayan Range. The MHNP spreads over an area of 173.9 km^2. The landscape comprises slopes, gullies, and limestone rocks, forming an excellent ravine habitat. MHNP altitude ranges from 450 to 1,580 m a.s.l. (Jabeen et al., 2009). The MHNP included the Margalla Hills, Rawal Lake, and Shakar Parian. It was given the status of a national park in 1980 after the government recognized the growing threats to its flora and fauna (Khan, 2004). This national park is an attractive destination for tourists and researchers. The climate of the MHNP is sub-tropical to semi-arid. The study area's average minimum and maximum temperatures are 34.3°C and 3.4°C, respectively (Shinwari and Khan, 2000). The area receives a reasonably high monsoon rainfall, and the annual rainfall is up to 1200 mm

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(Mahmood et al., 2021). As a result, the park has a rich diversity of flora and fauna. Dominant plant species of the park include *Pinus roxburghii, Mallotus philippensis, Bauhinia variegate, Cassia fistula, Carrisa apeca, Lantana camara, Dodonaea viscose, Justicia adhatoda*, etc. Among the plant species, few are invasive, and *Lantana camara* is the widest-spread invasive plant species in MHNP. Mammalian species found in MHNP include the common leopard (*Panthera uncia*), leopard cat (*Prionailurus bengalensis*), jungle cat (*Felis chaus*), red fox (*Vulpes vulpes*), jackal (*Canis aureus*), Indian Pangolin (*Manis crassicaudata*), barking deer (*Muntiacus muntjak*), etc.

Survey technique

Two survey techniques were used in the present study to obtain Indian pangolin presence locations in the MHNP.

Sign survey

A sign survey was carried out between May and June 2022 in the MHNP. The study area was divided into 1 × 1 km^2 grids of equal size (*Fig. 1*). The line transect method was employed to find the Indian pangolin signs or sights in the study area. Signs of the species were classified into; burrow (active or non-active), digging, scats, and pug marks. The burrow of the Indian pangolin was also categorized into feeding or resting burrows. A line transect equal to 39.71 km was walked in the study area, and the species' signs were recorded on a survey sheet. Circumference, diameter, and depth of each burrow were measured using a measuring tape. The age of the burrow or digging mark was noted based on the experience of MNHP wildlife watchers. Global Positioning System (GPS) reading of each presence location was marked.

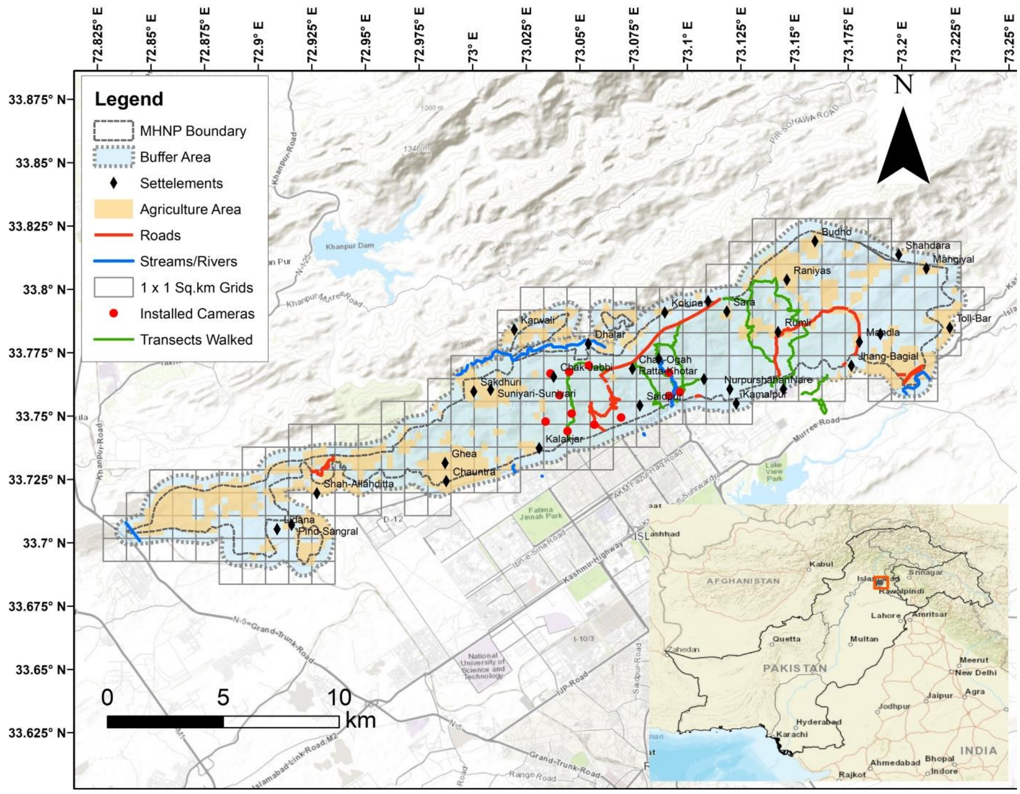

Figure 1. *Map of the study area along with line transects and camera stations*

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Camera trapping

Camera trapping is a noninvasive survey technique used in wildlife research to determine species' presence, abundance, etc. A camera trapping was conducted from 10-20 June 2022. In the present study, we only deployed 12 camera traps (UoVision AQ-HY505/EI Model 850, China) to confirm the Indian pangolin presence. The cameras were deployed 40-50 cm above the ground and mounted on trees. The vegetation in front of the camera sensor was removed, which can trigger the cameras, resulting in false photographs. In addition, the cameras faced north or south to avoid direct sunlight, which could trigger false images (Ahmad et al., 2016). All cameras were set to take three consecutive photos after 1-s intervals each time they were triggered.

Data analysis

We used ArcGis 10.8 to develop a study area map. We use the logistic regression model (GLM) in program R (version 4.2.2) to investigate the impact of the nearest settlement, nearest road, nearest water source, nearest forest, nearest agriculture land, slope and aspect on the presence of pangolin in MHNP, as given below:

$$\text{Presence} = glm\big(\text{Nearest}_{\text{Settlement}} + \text{Nearest}_{\text{Road}} + \text{Nearest}_{\text{Watersource}} + \text{Nearest}_{\text{Forest}} + \text{Nearest}_{\text{Agricultural}_{\text{Land}}} + \text{Slope} + \text{Aspect}, \quad \text{family} = \text{binomial}\big) \qquad \text{(Eq.1)}$$

The species' presence to the nearest distance of each variable was calculated using the proximity tool under analysis tools in ArcGIS 10.8. Slope and aspect angles were calculated using the spatial analyst tool in ArcGIS 10.8.

Model selection

The optimal GLM model that kept only significant factors was selected by stepwise model selection based on Akaike Information Criterion (AIC). Variance tables were analyzed to show the influential factors and the effect plots to study the relationship between the influential factors and response variables (Khattak et al., 2022a, b). Variables were considered significant at $p < 0.05$.

Results

Signs of Indian pangolin

In the current study, 51 signs of Indian pangolin were observed in the study area. Among the 51 signs, 32 were burrows, digging, and the pug marks were counted as 17 and two, respectively. Most of the burrows (97%) were categorized as inactive burrows, of which the pangolin used mostly (78.28%) for feeding purposes. On the other hand, most of the pangolin digging marks (94%) were found active. The average depth of the burrows was 36.36 inches (ranging from 0.3-3.1 m), while the average diameter and circumferences were recorded as 0.33 m (ranging from 0.15-0.76 m) and 1.02 m (ranging from 0.51-1.4 m), respectively.

Photo capture record

The cameras remained active in the study area for 132 trap nights. During this period, 4011 photos were recorded, including mammals, birds, humans and false

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photos. Key mammalian species included the common leopard, red fox, Asiatic jackal, wild boar, barking deer, porcupine, rhesus monkey, small Indian civet, Indian hare and Indian Pangolin. However, the Indian pangolin was photo-captured at only one camera station (*Fig. 2*).

Figure 2. *Indian pangolin recorded by camera traps at MHNP*

Factors affecting habitat selection of Indian pangolin

The GLM with logit link function that is logistic regression-based results are presented in *Table 1*. GLM accessed the impact of the nearest settlement, nearest road, nearest water source, nearest forest, nearest agricultural land, slope and aspect over the pangolin presence. It appears like the nearest road, nearest water source, nearest forest, nearest agricultural land, and slope seems statistically significant, affecting the presence of pangolin. The one-unit increase in distance from the road appears to decrease the likelihood of pangolin presence by 0.995 times (p = 0.018). Likewise, one unit increase in slope reduces the probability of pangolin presence by 0.286 times (p = 0.002). However, on the other hand, one unit increase in distance from the water sources, forest, and agricultural land increases the likelihood of pangolin presence by 1.001 times (p = 0.013), 1.014 times (p = 0.001) and 1.009 times (p = 0.001) respectively (*Table 1*).

Table 1. *The generalized linear model (GLM) with logit link function that is logistic regression-based results are presented (n = 51). GLM access the impact of nearest settlement, nearest road, nearest water source, nearest forest, nearest agricultural land, slope and aspect over the pangolin presence. Each row presents the odds ratio, logistic regression estimate, standard error and significance level (p-value) of respective factor*

	Odds ratio	Estimate	Std. error	p-value
(Intercept)	0.001	-11.136	8.873	0.209
Nearest_Settlement	1.004	0.004	0.003	0.172
Nearest_Road	0.995	-0.005	0.002	0.018
Nearest_Watersource	1.001	0.001	0.001	0.013
Nearest_Forest	1.014	0.014	0.004	0.001
Nearest_Agricultural_Land	1.009	0.008	0.003	0.001
Slope	0.286	-1.25	0.409	0.002
Aspect	1.001	0.001	0.051	0.996

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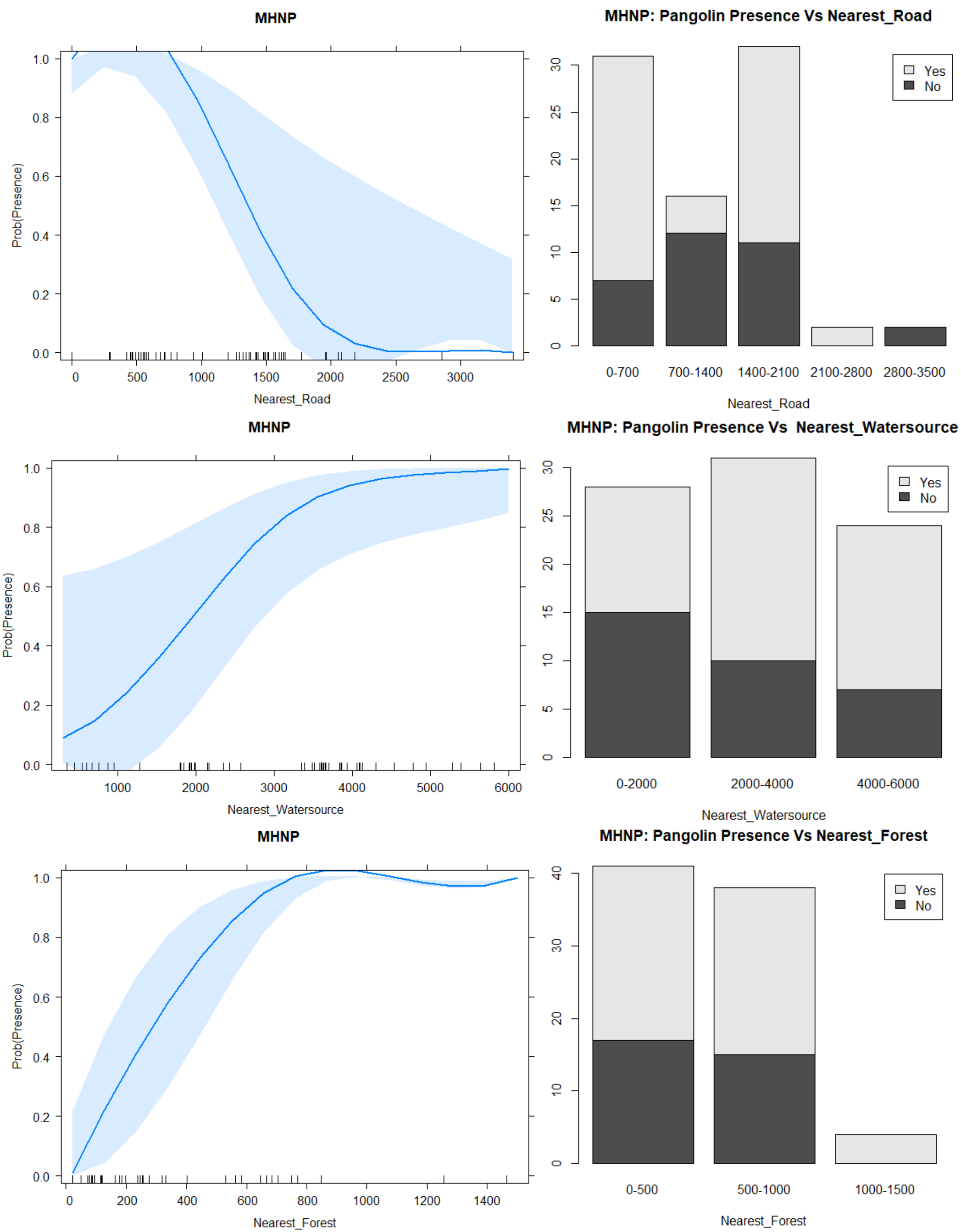
The probability of pangolin presence over the range of GLM-based statistically influential factors like nearest road, nearest water source, nearest forest, nearest agricultural land and slope is presented in the left panels of *Figure 3*. The increased distance from the road and slope increase decreases the likelihood of pangolin presence. Similarly, an increase in the distance from the water source, distance from the forest and the distance from agricultural land increase the likelihood of pangolin presence. The right panel of *Figure 3* presents the pangolin presence and absence over the intervals of respective influential factors for pangolin presence. This indicates most of the pangolins are at a distance of 0-700 and 1400-2100 m from the road, 2000-6000 m from the nearest water source, and 0-1000 m from the forest and at a distance of 0-2000 m from the agricultural lands. Similarly, most pangolins are present in areas with slopes from 0-10°.



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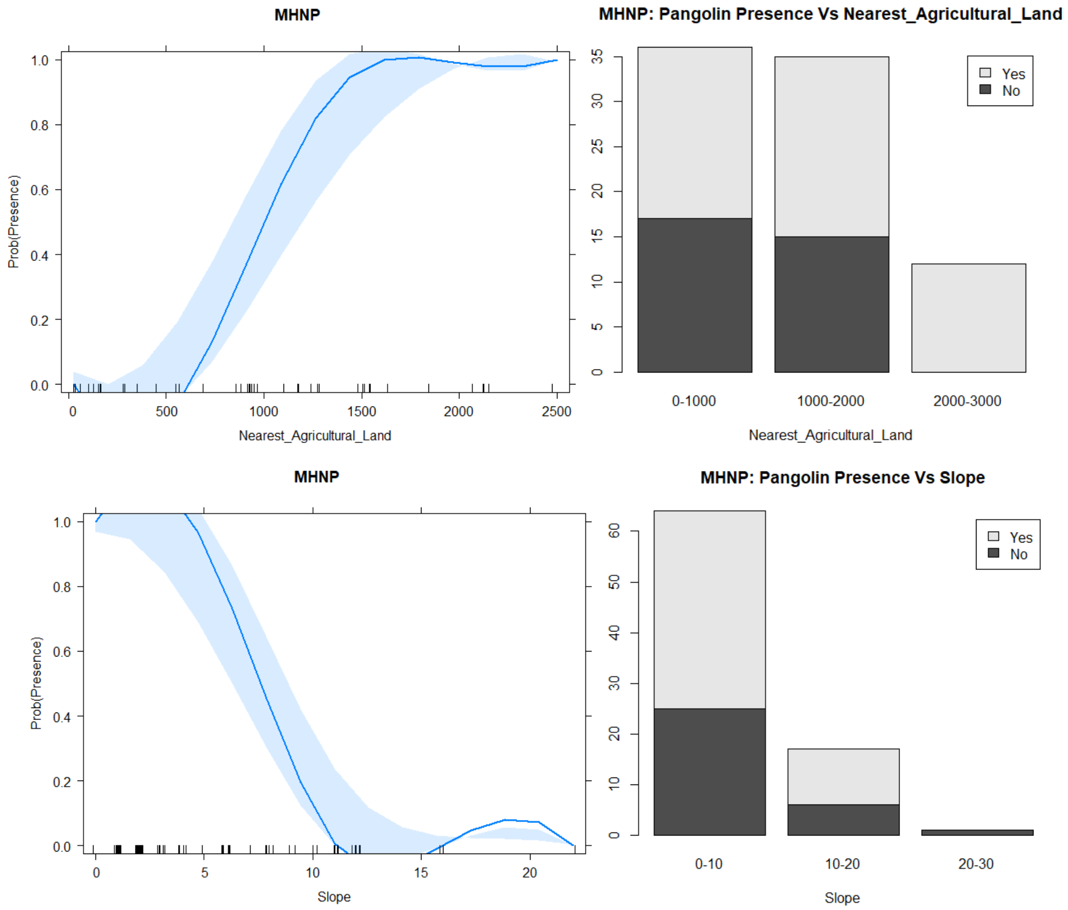

Figure 3. *The probability of pangolin presence over the range of GLM-based statistical influential factors. The right panel presents the pangolin presence and absence over the intervals of respective factors*

Discussion

To record the presence of Indian pangolin in the current study, we employed camera trapping along with sign surveys. Compared to other species, the detection rate was very low for Indian pangolin. One possible reason for such low detection may be less number of trap nights in the current study. However, Khwaja et al. (2019) reported that being predominantly a nocturnal and solitary species, pangolins have proven hard to detect—even with an exceptional number of trap nights.

Our results suggested that human settlements had no significant impact on the pangolin presence. Yet road distance was found to be inversely proportional to pangolin presence. However, we presume roads to be a kind of human settlement, and in this regard, several earlier studies support our findings. Sharma et al. (2020) documented 51% of pangolin presence within a 1000-m distance from human settlements, including roads. Similarly, findings by Karawita et al. (2018) revealed that pangolin presence was much more in areas with greater human disturbance and vice versa. In another study pangolin signs (burrows) were found to be more frequent near human disturbance in Nepal (Katuwal et al., 2013). We presume this observed presence of Indian pangolin nearer to roads is partly a consequence of the dispersion of human developmental processes within forested areas (Sharma et al., 2020).

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Pangolins prefer slopes less than 50° (Wu et al., 2003). Our results showed that increased slope significantly decreased the pangolin presence (*Fig. 3*). Findings by Shrestha et al. (2021) strongly support our results. The current study recorded the most pangolin presence in areas with slopes from 0-10°. Usually, pangolins prefer gentle slopes to steep slopes (Maurice et al., 2019). It is believed that avoidance of steeps by the species might facilitate locomotion in the area (Acharya et al., 2021) and avoid high energy expenditures during daily excursions—especially regarding ravine habitats. However, our results contradict the findings of Tamang et al. (2022), who reported Chinese pangolin preferences for steeper slopes in Nepal.

Water sources are one of the most important factors affecting the distribution of pangolins (Shrestha, et al., 2021). Pangolins need water, and ants, termites, and other insects also prefer moist habitats (Katuwal et al., 2013). However, our results showed that increased distance from water sources increases the likelihood of pangolin presence—thus, a contradiction exists with the studies mentioned above. Notably, our study areas harbor plenty of water sources, including the Kurang River, several streams, rain-filled holes and springs scattered throughout the park. However, our analysis only considered the main water bodies (rivers and streams). Thus, we presume that Indian pangolin in our study area mostly relies on the scattered rain-filled holes and springs. Therefore, we assume that the abundant supply of water sources in MHNP eased the need for the spatial selection of this resource (Tamang et al., 2022).

Indian Pangolin occupies various habitats, ranging from natural to anthropogenic (Karawita et al., 2018). However, our results showed that increased distance from forests and agricultural lands increases the likelihood of Indian pangolin. Our results are supported by findings from Mahmood et al. (2021). It has been reported that Chinese pangolin prefers agricultural lands due to the abundant supply of ants and termites due to cattle dung and plant debris (Richer et al., 1997; Tamang et al., 2022). However, excessive human disturbance in agricultural lands may limit prey availability and safe refuge—thus, pangolins may tend to avoid agricultural lands (Sharma et al., 2020). In addition, pangolins tend to occupy habitats with moderate to less canopy rather than thick forests (Bhandari and Chalise, 2014; Thapa et al., 2014; Dhakal, 2016; Dhital et al., 2020; Shrestha et al, 2021). This is because thick forest cover may retain the groundwater contents and limit the prey availability for pangolins, i.e. termites—occurring more in dry areas than wet areas (Karawita et al., 2018; Maurice et al., 2019a; Shrestha et al., 2021). In the meantime, pangolins are weak in defence against predators, and a moderate forest cover helps them to deter predators (Nowak and Walker, 1999; Maurice et al., 2019b). Based on our findings, we presume that the Indian pangolin does not exclusively inhabits forests or agricultural lands—yet prefers the areas in between to have safe refuge and better exploitation of resources simultaneously.

Conclusion

Our study provides insights into the site selection by Indian pangolin in a ravine habitat. Anthropogenic factors, including human settlements and roads, seem to have no negative impact on the pangolin presence; yet, the species prefers wild areas over agricultural lands. Based on the results obtained in the current study, we strongly recommend enhancing watch and ward practices in the buffer areas of the MHNP comprising settlements and roads—to control poaching and illegal trade. In addition, areas with slopes lower than 50° should be managed and persevere from erosion and

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degradation. Moreover, we strongly recommend to carry out studies round the year and to make use of the more sophisticated tools like radio telemetry or GPS transmitter to have better information on habitat selection by this endangered species.

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