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ARTICLE

Factors affecting the occupancy of Chinese pangolins (*Manis pentadactyla*) suggest a highly specialized ecological niche

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Abstract

The Chinese pangolin is a critically endangered and biologically unique species, yet information on its status, distribution, and habitat preferences is still scarce in Nepal, which limits effective conservation action. This study identified the current burrow density status, distribution pattern, and important habitat parameters associated with Chinese pangolin distribution in Nepal through opportunistic field surveys. Fifty-four belt transects were examined for the presence of pangolin burrows. For each active burrow (burrow with freshly dug soil, footprints, and scat near the entrance) and old burrow (burrow with compacted soil, presence of dead leaves, and spider web in the entrance), we recorded the geographic coordinates and assessed data on 11 habitat parameters that included elevation, aspect, slope, canopy cover, ground cover, presence or absence of ant and termite colonies, habitat type, soil type, and distances to the nearest water source, road, and settlement. A total of 141 active burrows and 430 old burrows were recorded with an overall clumped distribution $\{(S^2/a) = 2.188\}$. Active burrow density was estimated to be 1.04 burrows/ha. Of the 11 habitat parameters predicted to influence the probability of encountering pangolin burrows, all parameters were significant except elevation. More than 92% of the burrows were found at elevations between 450 and 750 m and facing either the SE or NW aspect. Similarly, about 90% of the burrows were distributed in areas having slopes between 0% and 30% with moderate to high canopy and ground cover, and located close to water sources, roads, and settlements. Additionally, they strongly preferred forest habitats (with *Shorea robusta*, *Castanopsis indica*, *Schima wallichii*, *Clerodendron infortunatum*, and *Nephrolepis auriculata* as the dominant vegetation), areas with red soil, and areas located near ant and termite colonies.

Although the study area currently provides suitable habitat for Chinese pangolins, it is slowly being degraded due to increasing rates of forest degradation. Conservation efforts should be increased in order to protect this critically endangered species and their preferred habitats. Finally, our findings reveal the preferred habitat characteristics of Chinese pangolins, which could be instrumental for policy makers and forest managers in making conservation plans for Chinese pangolins.

KEYWORDS
belt transect, burrows, habitat parameters, *Manis pentadactyla*, Nepal, opportunistic survey, specialist

INTRODUCTION

Among the eight pangolin species worldwide (four Asian species and four African species), two species are found in Nepal: the Indian pangolin (*Manis crassicaudata*) and the Chinese pangolin (*Manis pentadactyla*) (Baral & Shah, 2008; DNPWC, 2018; Jnawali et al., 2011). The global distribution of the Chinese pangolin has been reported to span Bangladesh, Bhutan, China, Hong Kong, India, Lao People's Democratic Republic, Myanmar, Nepal, Taiwan, Thailand, and Vietnam at elevations of up to 3000 m (Challender et al., 2019). The first national survey of pangolins in Nepal in 2016 revealed that the Chinese pangolin is distributed in 25 districts in Nepal, including Gorkha (DNPWC, 2018). Chinese pangolins utilize a wide range of habitats including primary and secondary tropical forest, limestone forest, bamboo forest, grassland, and agricultural lands (Gurung, 1996; Katuwal et al., 2017), where they either dig their own burrow or enlarge passages made by termites (Newton et al., 2008; Wu et al., 2005).

Currently, the global population of the Chinese pangolin has not been assessed; however, its populations are known to be decreasing and the species is listed as critically endangered under the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (Challender et al., 2019) and listed in CITES Appendix I by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 2020). In addition, the population of Chinese pangolins in Nepal is estimated to be around 5000 individuals, and the species is protected in Nepal under the National Parks and Wildlife Conservation (NPWC) Act of 1973 (DNPWC, 2022; GoN, 1973; Jnawali et al., 2011; Thapa, 2013; Wu et al., 2020). In recent decades, the pangolin population has declined significantly due to rampant hunting and poaching for its meat and scales, which are primarily targeted for international trade and driven by high demand in China and Vietnam (Challender et al., 2019; Heinrich et al., 2017; Newton et al., 2008; Zhang et al., 2017). Furthermore, recent increases in anthropogenic activities, such as the expansion of settlements, road and dam construction, conversion of forest to agricultural land, forest fires, overgrazing, extraction of soil for domestic use, and loss of natural water sources (DNPWC, 2018), are becoming key threats to biodiversity conservation, including for the Chinese pangolin. These activities have negative impacts on wildlife, particularly those that are highly vulnerable to extinction (Pereira et al., 2004), such as small mammals that have highly specialized ecological niches and are therefore less ecologically flexible (Büchi & Vuilleumier, 2014; Mattos et al., 2021). Thus, knowledge about the ecological drivers that influence habitat preference and distribution patterns is essential for the conservation and management of threatened wildlife (Aarts et al., 2008; Bajaj & Amali, 2019; Balakrishnan & Easa, 1986).

Despite legal protection and being critically endangered in IUCN Red List status (Challender et al., 2019), the Chinese pangolin is in peril (Ghimire et al., 2020), and is one of the least-studied burrowing mammals. Moreover, we lack information about populations at both the global and national levels (Challender et al., 2019). Numerous studies have been conducted nationally, focusing on the illegal trade of pangolins (Bashyal et al., 2021; Ghimire et al., 2020; Katuwal et al., 2015; Sharma, Sharma, Katuwal, et al., 2020). Only a few studies are available that focus on the distribution and habitat preference of this critically endangered species (Acharya et al., 2021; Aryal & Poudel, 2018; Katuwal et al., 2017; Rai et al., 2019; Sharma, Sharma, Chaulagain, et al., 2020; Shrestha et al., 2021). Still, there is a substantial gap in our knowledge about the habitat use and preferences of Chinese pangolins in Nepal (DNPWC, 2018; Jnawali et al., 2011). Prior research reveals that almost all potential habitat that is suitable for the Chinese pangolin occurs outside of protected areas in Nepal (Sharma, Rimal, Zhang, et al., 2020). A lack of interest by the general public, combined with increasing wildlife trafficking and habitat destruction, contributes to current population declines in this species. This study therefore aims to examine the current burrow density status, distribution pattern, and habitat preference of Chinese pangolins in the Palungtar and Gorkha municipalities of Gorkha district, which is regarded as a hotspot for this species. We expect that this research will provide urgently needed information about the distribution, burrow density status, and habitat characteristics of the Chinese pangolin, which will contribute for effective planning and management of this species and their preferred habitat.

MATERIALS AND METHODS

Study area

Chinese pangolins have been sighted in different locations of Gorkha district, but there is very little documented evidence (DNPWC, 2018). Community forests (CFs) are considered as the prime pangolin habitat in Gorkha district. Thus, eight CFs from two municipalities, namely, Gorkha (three CFs) and Palungtar (five CFs), of Gorkha district, Nepal were selected for this study. CFs are parts of national forests that are handed over to the local CF user group with entitlement to develop, conserve, use and manage the forest, and to sell and distribute forest products independently by setting prices according to a work plan approved by the Division Forest Office (GoN, 2019). The user groups perform different maintenance activities such as cleaning, pruning, thinning, and felling regularly, with the right to introduce forest-based enterprises, which results in high human intervention in these forested areas. Since 1978, over 22,000 national forests have been handed over to local communities (Pandey & Pokhrel, 2021). The study district is in Gandaki Province at an elevation of 1106 m above mean sea level (amsl) (27°59′46.392″ N, 84°37′44.688″ E) (Figure 1). Gorkha district has a subtropical climate and covers an area of 3610 km^2, bordered by Tibet to the north, Tanahun district and Chitwan district to the south, Lamjung district to the west, and Dhading district to the east. It has two municipalities, Gorkha (28.00° N, 84.33° E) and Palungtar (28.05° N, 84.50° E), and seven rural municipalities. The major vegetation of the area includes *Schima wallichii*, *Shorea robusta*, *Castanopsis indica*, *Alnus nepalensis*, *Choerospondias axillaris*, *Albizia* species, and *Myrica esculenta*. Common faunal species in the area include Chinese pangolins (*Manis pentadactyla*), porcupines (*Hystrix* spp.), leopards (*Panthera pardus*), the small Indian mongoose (*Herpestes auropunctatus*), the Indian crow (*Corvus splendens*), the common pigeon (*Columba livia*), and the common myna (*Acridotheres tristis*).

Data collection

The study was conducted from 7 January to 26 February 2021, as Chinese pangolins are active during the breeding season (February–July) (Wu et al., 2020).

Preliminary survey

A preliminary field visit was carried out between 7 and 15 January, and potential sites of Chinese pangolin occurrence were confirmed after consultation with locals, as well as staff members of both the Division Forest Office (DFO) and the Federation of Community Forestry Users Nepal (FECOFUN). Moreover, local people and experts were interviewed about the ecology and behavior of Chinese pangolins, along with the date, year, and time of any encounters, and photographic evidences of rescued individuals. Additionally, an intensive literature search revealed 18 key parameters (elevation, aspect, slope, canopy cover, ground cover, presence or absence of ant and termite colonies, habitat type, soil type, forest fire frequency, livestock grazing intensity, deforestation rate, litter depth, temperature, rainfall, humidity, and the distances to the nearest water source, road, and settlement) influencing the habitat use of the Chinese pangolin across its distribution range (Bhandari & Chalise, 2014; DNPWC, 2018; Dorji et al., 2020; Katuwal et al., 2017; Suwal et al., 2020; Wu et al., 2004, 2020). Most of the studies that were conducted in areas similar to our geographical region and setup reported 11 habitat parameters (elevation, aspect, slope, canopy cover, ground cover, presence or absence of ant and termite colonies, habitat type, soil type, and the distances to the nearest water source, road, and settlement) to have a major influence on pangolin distribution and habitat use (Acharya et al., 2021; Aryal & Poudel, 2018; Katuwal et al., 2017; Shrestha et al., 2021; Suwal et al., 2020). Furthermore, the selection of these habitat parameters was confirmed after discussion with field-experienced locals and pangolin experts in Nepal.

Transect surveys

It is difficult to monitor pangolins due to their nocturnal, elusive, and burrow-dwelling characteristics (Willcox et al., 2019). Indirect signs, especially the presence of burrows, are regarded as indicators of the presence of Chinese pangolins in the study area (Wilson & Delahay, 2001). To study burrowing animals like pangolins, transects in combination with the burrow count method are widely used (Ingram et al., 2019). We established a total of 54 belt transects (500 × 50 m each) at

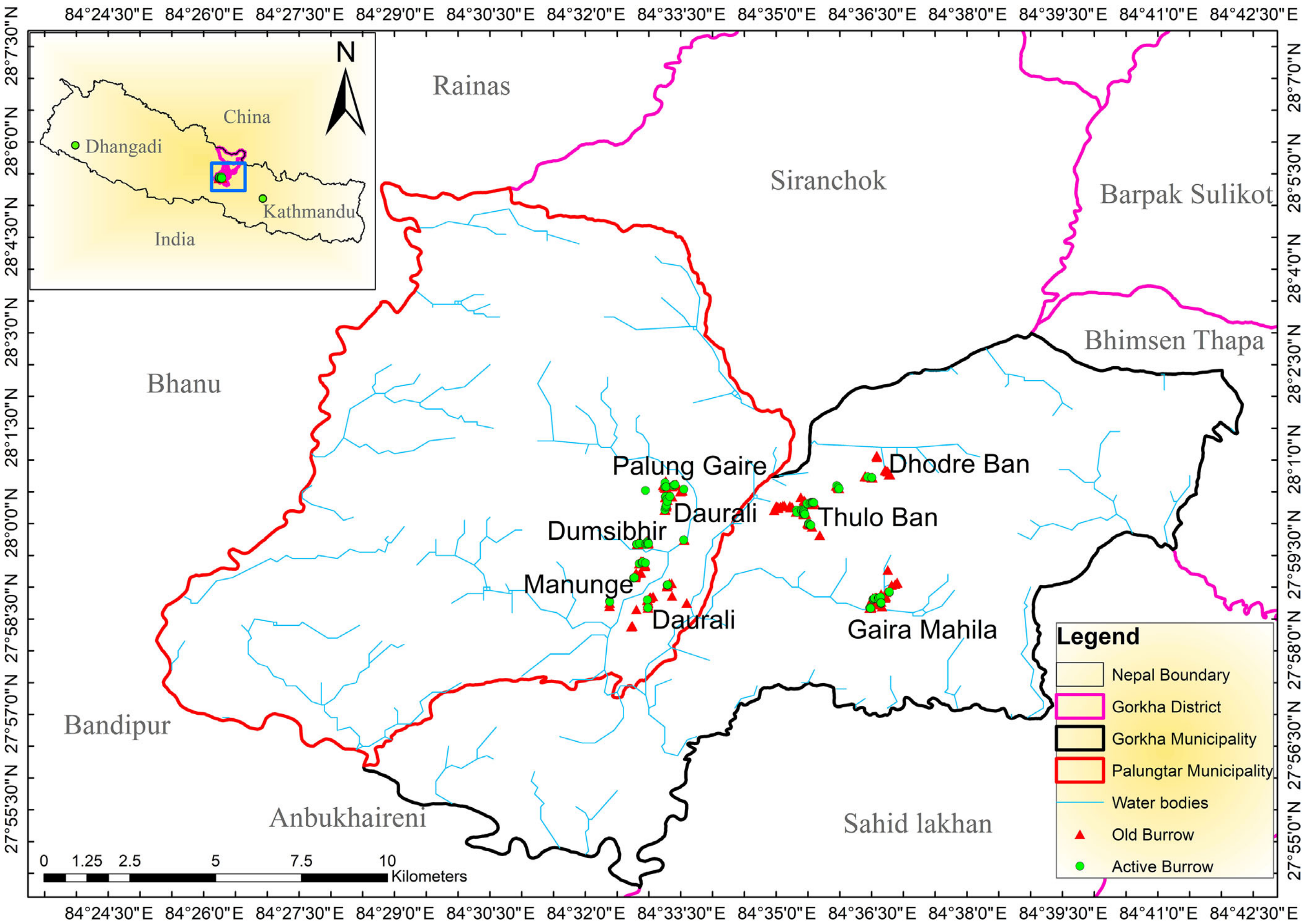

FIGURE 1 Map of the study area showing the distribution pattern of old and active burrows of Chinese pangolins. The burrows are distributed in eight community forests within Gorkha and Paluntar municipalities of Gorkha district, Nepal.

potential sites in our study area. The distance between two transects was 200 m, to minimize the possible overlapping of burrow construction by a single pangolin individual. A team of three experienced field technicians, who already had some level of firsthand field experience researching pangolins, intensively searched for burrows (both active and old) and other signs of pangolin presence (e.g., digs, pugmarks, scales, and scat) making sure that no burrows were missed within each belt transect (i.e., up to 25 m on either side of the centerline). Also, during the winter season, there is thinner vegetation in the forest (Neupane et al., 2022; Safford, 2004; Sanusi et al., 2013), which increased the probability of burrow detection. Burrows with freshly dug soil, footprints, and scat near the entrance were categorized as active, while burrows with compacted soil, presence of dead leaves, and spider webs in the entrance were categorized as old (DNPWC, 2019). Among the old burrows, burrows with spider webs in the entrance were recognized as "unused" (not used for a long time) and this was further confirmed by consultation with pangolin experts in Nepal. For each of the active and unused burrows, we established a 10 × 10-m plot from the center of each burrow (Dhital et al., 2020) and recorded all habitat characteristics (latitude and longitude, elevation, aspect, slope, canopy cover, ground cover, presence or absence of ant and termite colonies, habitat type, and soil type), as well as the distances to the nearest water source, road, and settlement. However, the conditions at the unused burrows alone might not represent the overall habitat conditions of the study area, so to minimize this bias, we established plots (the same size as were established around active and unused burrows) 200 m uphill and 200 m downhill randomly from each active burrow (Aryal & Poudel, 2018) and assessed the same habitat parameters. The plots around unused burrows and the random plots at 200 m from active burrows were considered as habitat availability plots, and plots with active burrows were categorized as in-use plots (Neupane et al., 2022). We measured elevation with a handheld GPS (Garmin Etrex 30) and aspect using the compass application on an iPhone7 Plus (model number MNR52LL/A). We obtained information about the slope of the entire study area from digital elevation model (DEM, 12.5 m resolution) (ASF, 2021) and used the Slope tool in ArcGIS 10.8 to determine the slope at each burrow. In addition, we measured ground and canopy cover using an iPhone. The iPhone was placed at eye level (1.57 m) using a tripod. Photographs of the ground and canopy cover were taken from each of the four corners of the plot as well as the center of the plot, and the average ground and canopy coverage for each plot was calculated. To determine the distances to the nearest road and settlement, we extracted the road and settlement shapefile from Open Street Map (OSM, 2021) and used the Near analysis tool in ArcGIS 10.8. Furthermore, the distance to the nearest water source was calculated by extracting the shapefiles of surface water from DEM (12.5-m resolution) (ASF, 2021) and Landsat Image 8 (USGS, 2021) and then using the Near analysis tool in ArcGIS. Habitat type (forest, grassland, barren land, or agricultural land), soil condition (red, brown, or reddish-brown), and presence or absence of ant and termite colonies were recorded based on direct observation during the field visit.

Vegetation survey

For vegetation analysis, quadrats were established at three layers: 10 × 10 m for trees (dbh of at least 10 cm), 4 × 4 m for shrubs (woody plant with height >1.0 m and dbh <10 cm), and 1 × 1 m for herbaceous species, as suggested by Schemnitz (1980) (Figure 2). For trees and shrubs, we measured the dbh and counted the number of individuals of each species, and for herbaceous plants, we measured the approximate coverage of each species.

Data analysis

Burrow distribution of the Chinese pangolin

For estimating the burrow density of Chinese pangolins, only active burrows were considered to indicate pangolin presence (i.e., old burrows were scored as pangolins absent; Bhandari & Chalise, 2014; Sharma, Sharma, Chaulagain, et al., 2020). Burrow density (D) was estimated using the following formula:

$$D = \frac{\text{Total number of active burrows}}{\text{Total area surveyed across the transects}}.$$

Additionally, the distribution of Chinese pangolin burrows was determined by calculating the variance to mean ratio $\left(S^2/a\right)$ (Odum, 1971), where variance is calculated as $S^2 = \frac{1}{n}\sum(x-a)^2$, x is the sample value, and a is the mean value. A $\left(S^2/a\right)$ ratio equal to one indicates a random distribution, a ratio less than one indicates a uniform distribution, and a ratio greater than one indicates a clumped distribution.

Vegetation analysis

Vegetation analysis was conducted following Smith (1980) using the following formulas:

1. Density of species A
$$= \frac{\text{Total number of individuals of species A}}{\text{Total number of areas surveyed} \times \text{area of plot}}$$
2. Relative density of species A
$$= \frac{\text{Total number of individual of species A} \times 100}{\text{Total number of individuals of all species}}$$
3. Frequency of species A
$$= \frac{\text{Number of plots in which species A occurs} \times 100}{\text{Total number of plot samples}}$$
4. Relative frequency of species A
$$= \frac{\text{Frequency value of species A} \times 100}{\text{Total frequency value of all species}}$$
5. Cover % A
$$= \frac{\text{Approximate area covered by species A} \times 100}{\text{Total number of plots sampled}}$$

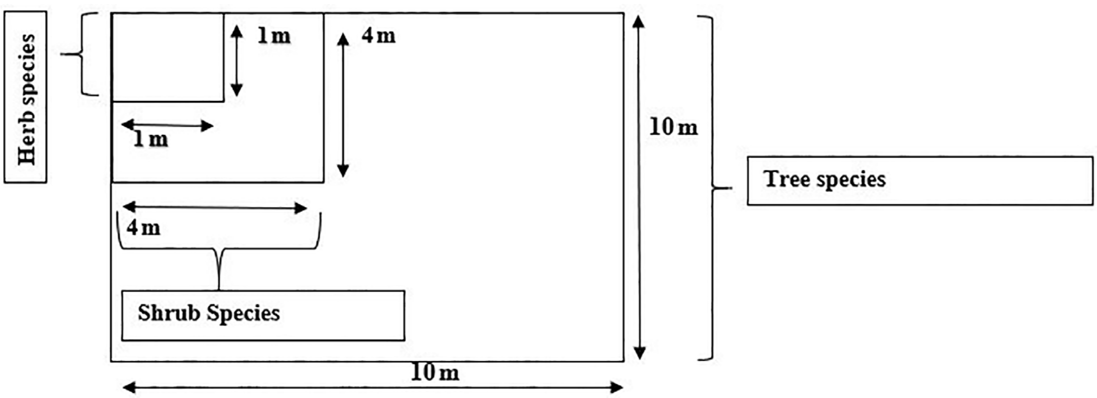

FIGURE 2 Diagram of the vegetation survey quadrats used to evaluate site use by pangolins in Nepal.

6. Relative cover A

$$= \frac{\text{Cover of species A} \times 100}{\text{Total cover of all species}}$$

7. Relative dominance of species A

$$= \frac{\text{Total basal area of species A} \times 100}{\text{Total basal area of all species}}$$

where the basal area of species A $= \pi(d^2/4)$, where d is the diameter at breast height.

The importance value index (IVI) for trees and shrubs was calculated as the sum of relative density, relative frequency, and relative dominance, while for herbaceous species IVI was calculated as the sum of relative density, relative frequency, and relative cover.

Habitat preference of Chinese pangolin

A binomial distribution model with logit link function ($\log(y/1-y)$) was utilized to explore the habitat factors influencing the presence of Chinese pangolins in the study area. The presence or absence of active burrows ("1" for in-use plots and "0" for habitat availability plots) was used as the dependent variable. The 11 predetermined habitat variables (described in *Transect surveys*) were included as independent variables. For the independent variables, a multicollinearity test was executed based on variance inflation factor (VIF) analysis (Montgomery et al., 1982) using the package "Faraway" (Boomsma, 2014). The predetermined variables did not exhibit multicollinearity, as VIF values were not greater than 10 (Bowerman & O'connell, 1990). To determine the habitat factors influencing Chinese pangolin occurrence in our study area, we performed logistic regression analysis, where all habitat parameters were entered into an initial model, and data were considered for over-dispersion. The summary table of the model indicated that the data were not over-dispersed. Backward selection was performed (stepwise removal of insignificant variables using likelihood ratio tests), and the final model was determined when no further variables could be eliminated (i.e., all remaining variables in the model were significant, $p < 0.05$). All analyses were performed using R version 4.0.3 (R Core Team, 2020).

RESULTS

Burrow density status and distribution of Chinese pangolins

We recorded 571 Chinese pangolin burrows (141 active and 430 old) in eight CFs located in the Gorkha and Palungtar municipalities of Gorkha district, Nepal. The majority of the burrows were found in Thulo Ban CF ($N = 158$, active $= 40$, and old $= 118$), which was dominated by *S. robusta*, *S. wallichii*, and *C. indica* forests having a SE- or NW-facing slope of 0%–15%, followed by Manunge CF ($N = 75$, active $= 11$, old $= 64$), and the fewest burrows were found in Dhodre Ban CF ($N = 40$, active $= 3$, old $= 37$) dominated by *S. wallichii* and *Albizia odorattisima* (see details in Table 1). These results suggest that the distribution of burrows is not uniform. The detailed characteristics of these areas are described in the habitat preference section below.

The overall distribution of Chinese pangolin burrows in the study area was clumped, as the observed variance to mean ratio (2.188) is >1 (Figure 1). Furthermore, the active burrow density was 1.04 burrows/ha.

Habitat attributes associated with the observation of Chinese pangolin burrows

The majority of active burrows were found at elevations between 450 and 600 m on SE- and NW-facing slopes (0%–15% incline). Moreover, the majority of active burrows were recorded in areas with moderate canopy cover (26%–50%) and ground cover (51%–75%). Active burrows were distributed in the vicinity of water sources, human settlements, and roads. Furthermore, the majority of active burrows were recorded in forested habitat and in red soil. Finally, active burrows were recorded in areas with ant and termite colonies (Table 2).

Probability of sighting Chinese pangolin burrows in relation to different habitat parameters

Results from the logistic regression model revealed that, of the 11 habitat parameters, only elevation was not

TABLE 1 Numbers of burrows of Chinese pangolin located in eight community forests of the study area.

Community forest	Total no.	No. active	No. old
Thulo Ban	158	40	118
Gaira Mahila	72	29	43
Dhodre Ban	40	3	37
Daraudi Danda	56	14	42
Manunge	75	11	64
Dumsibhir	61	19	42
Daurali	49	14	35
Palung Gaire	60	11	49
Total	571	141	430

TABLE 2 The number and percentage of active burrows of Chinese pangolin associated with each habitat parameter recorded during the field survey in the study area.

Habitat parameter	No. active burrows	Percentage (%)
Elevation (m)		
450–600	76	53.9
601–750	54	38.3
701–900	11	7.8
Aspect		
East	22	15.6
West	11	7.8
North	17	12.1
South	9	6.4
Northeast	14	10
Northwest	26	18.4
Southeast	26	18.4
Southwest	16	11.3
Slope (%)		
0–15	68	48.2
16–30	58	41.1
31–45	15	10.7
Canopy cover (%)		
0–25	38	27
26–50	56	39.7
51–75	43	30.5
75–100	4	2.8
Ground cover (%)		
0–25	17	12
26–50	50	35.5
51–75	57	40.4
75–100	17	12.1
Distance to nearest water source (m)		
0–100	80	56.7
101–200	39	27.7
201–300	7	5
301–400	9	6.4
401–500	6	4.2
Distance to nearest settlement (m)		
0–700	81	57.5
701–1400	44	31.2
1401–2100	14	9.9
2101–2800	2	1.4
Distance to nearest road (m)		
0–700	69	49
701–1400	59	41.8

(Continues)

TABLE 2 (Continued)

Habitat parameter	No. active burrows	Percentage (%)
1401–2100	12	8.5
2101–2800	1	0.7
Presence/absence of ant colonies		
Yes	101	71.6
No	40	28.4
Habitat type		
Forested land	94	66.7
Agricultural land	19	13.5
Barren land	10	7
Grassland	18	12.8
Soil type		
Red	91	64.6
Brown	34	24.1
Reddish-brown	16	11.3

significant ($p = 0.208$). However, the probability of observing Chinese pangolin burrows was significantly influenced by aspect, slope, canopy cover, ground cover, distance to nearest water source, distance to nearest settlement, distance to nearest road, presence of ant and termite's colonies, habitat type, and soil condition (Table 3).

Vegetation dominance

Tree dominance

Altogether, we identified 12 species of trees and found that *S. robusta* (Sal) (IVI = 107.02) is the most dominant species in the study area, followed by *S. wallichii* (Chilaune) (IVI = 82.28) and *C. indica* (Dhalne Katus) (IVI = 54.05), while *Syzygium cumini* (Jamun) is the least dominant species (IVI = 2.1) (Table 4).

Shrub dominance

In total, we identified 10 species of shrub in the study area. Among them, *Chlaeodendron infortunatum* (Bhat) (IVI = 83.3) is the most dominant species, followed by *Lantana camara* (lantana) (IVI = 47.35) (Table 5).

Herb dominance

We recorded 12 species of herbaceous plants in our study area and found *Nephrolepis auriculata* (Pani amala)

TABLE 3 Significance of habitat parameters (aspect, slope, canopy cover, ground cover, presence or absence of ant and termite colonies, habitat type, soil type, and distances to the nearest water source, road, and settlement) predicting the detectability of Chinese pangolin burrows in the study area.

Predictor	Estimate	SE	χ^2	p
Intercept	−1.85750	0.53809		
Aspect			15.953	0.025545*
East	0			
North	0.16986	0.56316		
Northeast	−0.43334	0.52868		
Northwest	−0.98036	0.56774		
South	−1.33472	0.60776		
Southeast	−0.85598	0.51580		
Southwest	−2.02468	0.76625		
West	−0.52288	0.56457		
Slope			75.529	<2.2e−16***
0–15	0			
16–30	−1.61371	0.37567		
31–45	7.60220	1.93738		
Canopy cover (%)			34.201	1.797e−07***
0–25	0			
26–50	−1.65296	0.45375		
51–75	−2.88838	0.54272		
76–100	−2.01781	1.41766		
Ground cover (%)			59.378	7.981e−13***
0–25	0			
26–50	1.75243	0.68095		
51–75	6.28868	1.16851		
76–100	4.31638	1.13934		
Distance to nearest water source (m)			27.328	1.706e−05***
0–100	0			
101–200	−3.64227	0.98290		
201–300	−4.58341	1.28239		
301–400	−3.76190	1.31905		
401–500	0.63378	0.89069		
Distance to nearest settlement (m)			25.102	1.470e−05***
0–700	0			
701–1400	0.97144	0.39845		
1401–2100	−0.31002	0.86892		
2101–2800	−3.91220	1.71191		
Distance to nearest road (m)			20.511	0.000133***
0–700	0			
701–1400	1.78565	0.46536		
1401–2100	−0.36848	0.97529		
2101–2800	−1.87838	1.86650		
Presence of ant/termite colonies			8.599	0.003363**
No	0			
Yes	0.86178	0.30199		
Habitat type			14.909	0.001896**
Agricultural land	0			
Barren land	−1.22773	0.79089		
Forested land	1.13808	0.64293		
Grassland	0.07462	0.77495		
Soil type			10.563	0.005084**
Brown	0			
Red	0.04769	0.33177		
Reddish-brown	−2.05564	0.68775		

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

(IVI = 53.28) to be the most dominant species, followed by *Cynodon dactylon* (Dubo) (IVI = 39.3) and *Imperata cylindrica* (IVI = 38.47) (Table 6).

DISCUSSION

By identifying the distribution, current burrow density status, and key habitat factors influencing pangolin burrows, our findings reveal a critical aspect of Chinese pangolin conservation in the human-dominated landscape of Nepal's western mid-hills. Our findings are expected to benefit Chinese pangolin conservation efforts in Nepal's western mid-hills, which, despite strong human pressure, is the main habitat of this species. A study by Sharma, Rimal, Zhang, et al. (2020) revealed that the distribution of Chinese pangolins is concentrated in the forested mid-hills of Nepal, but many mid-hill districts have not yet been studied. Given the scarcity of knowledge on the Chinese pangolin, our study is expected to contribute to a better understanding of the species and aid conservation efforts in these human-dominated settings.

Before 2000, pangolin distribution had only been reported in 13 of 77 districts in Nepal, primarily from the

TABLE 4 Important value index of tree species recorded in the habitat of Chinese pangolin.

Tree species	RA	RF	RD	IVI
Adina cordifolia (Karma)	1.2	1.06	0.98	3.24
Albizia odorattisima (Padke)	3.94	1.86	5.3	11.1
Castanopsis indica (Dhalne Katus)	16.95	17.55	19.55	54.05
Engelhardia spicata (Mauwa)	2.4	2.13	2.5	7.03
Lagerstroemia parviflora (Bot Dhaiyanro)	1.54	1.33	1.22	4.09
Schima wallichii (Chilaune)	27.57	29.79	24.92	82.28
Semecarpus anacardium (Bhalayo)	3.42	2.13	4.04	9.59
Shorea robusta (Sal)	35.2	38.3	33.61	107.02
Syzygium cumini (Jamun)	0.68	0.8	0.62	2.1
Terminalia alata (Asna)	2.74	2.39	2.1	7.23
Terminalia bellerica (Barro)	2.4	1.33	1.56	5.29
Terminalia chebula (Harro)	2.05	1.33	3.6	6.98
Total	100	100	100	

Abbreviations: IVI, important value index; RA, relative density; RD, relative dominance; RF, relative frequency.

TABLE 5 Important value index of shrub species in the habitat of Chinese pangolin.

Shrub species	RA	RF	RD	IVI
Berberis asiatica (Chutro)	9.76	9.76	22.18	41.7
Calotropis gigantea (Canopy flower)	8.54	8.54	10.21	27.29
Chlaeodendron infortunatum (Bhat)	28.86	28.86	25.58	83.3
Lantana camara (lantana)	17.89	17.89	11.57	47.35
Maesa indica (Krimighna phal)	4.47	4.47	5.7	14.64
Melastoma malabathricum (Angari)	9.76	9.76	6.6	26.12
Rubus alceifolius (Giant Bramble)	3.25	3.25	3.62	10.12
Rubus ellipticus (Golden Evergreen Raspberry)	8.94	8.94	10.13	28.01
Woodfordia fruticosa (Fireflame bush)	1.63	1.63	1.15	4.41
Zizphus jujuba (Bayer)	6.91	6.9	3.26	17.06
Total	100	100	100	

Abbreviations: IVI, important value index; RA, relative density; RD, relative dominance; RF, relative frequency.

central and eastern districts (Corbet & Hill, 1992; Gurung, 1996; Hodgson, 1836; Suwal et al., 1995). Furthermore, between 2000 and 2017, the presence of pangolins was only recorded in 10 districts (Bhandari, 2013; Kaspal, 2008; Katuwal et al., 2015, 2017; Sapkota, 2016; Shrestha & Basnet, 2005; Suwal, 2011; Thapa et al., 2014). During the first national survey of Chinese pangolins in 2016, the species was recorded in 25 districts, including Gorkha district (DNPWC, 2018).

The majority of the burrows recorded in the study area were old. This finding may be because pangolins mainly utilize feeding burrows for a limited time before switching to a new burrow (Lin, 2011). Furthermore, male pangolins can occupy approximately 80 resident burrows and female pangolins can occupy approximately 30–40 burrows in their home range (Challender et al., 2019). Additionally, according to Mro hunters in Bangladesh, a pangolin can excavate up to 15 feeding burrows in a night, and resident burrows can reach up to 10 m deep (Trageser et al., 2017). The majority of the burrows were distributed in Thulo Ban CF followed by Malunge CF and Gaira Mahila CF. These forests had similar vegetation (*S. wallichii*, *S. robusta*, and *C. indica*) and a high availability of food (ants and termites) and water resources. The number of burrows was less frequent at the high-elevation site (Dhodre Ban CF) as the availability of food resources for pangolins at higher elevation zones is scarce (Gathorne-Hardy et al., 2001; Hemachandra et al., 2014). Similar results were observed in other parts of the world, for example, in Bhutan (Dorji

TABLE 6 Important value index of herbaceous species in the habitat of Chinese pangolin.

Herb species	RA	RF	RC	IVI
Cynodon dactylon (Dubo)	21.51	10.4	7.39	39.3
Sphaeranthus indicus	6	6.38	3.4	15.78
Mimosa pudica (Shame Plant)	4.24	8.05	4.63	16.92
Ipomoea obscura	3.52	10.4	10.62	24.54
Eupatorium adenophorum (Crofton weed)	10.42	8.72	9.27	28.41
Nephrolepis auriculata (Pani amala)	14.99	17.45	20.84	53.28
Cissampelos pariera (Batul pate)	1.62	3.69	4.36	9.67
Acmella uliginosa (marsh para cress)	5.43	5.03	7.11	17.57
Dryopteris spp.	7.9	10.07	10.84	28.81
Oxalis spp.	6.28	3.69	5.83	15.8
Digitaria sanguinalis	1.52	5.37	4.56	11.45
Imperata cylindrica	16.57	10.75	11.15	38.47
Total	100	100	100	

Abbreviations: IVI, important value index; RA, relative density; RC, relative cover; RF, relative frequency.

et al., 2020). Moreover, the distribution of burrows in our study area was not uniform. Previous studies have also reported nonuniform distributions of burrows (Bhandari & Chalise, 2014; Suwal, 2011), similar to our study.

In our study, the active burrow density was found to be 1.04 burrows/ha. The active burrow density recorded by Bhandari and Chalise (2014) in the Nagarjun forest of Shivapuri Nagarjun National Park was 0.83 burrows/ha. However, estimates of burrow density vary, as the total burrow density recorded by Kaspal (2008) in the Nagarjun forest of Shivapuri Nagarjun National Park was 0.102 burrows/ha and burrow density recorded by Suwal (2011) in private and CFs of Balthali in Kavre was 8 burrows/ha. The burrow density found in our study was generally higher than those of other studies, possibly due to the high availability of ants and termites coupled with other favorable habitat conditions. The availability of ants and termites is an important factor that determines the distribution of pangolins (Swart et al., 1999).

The two species of pangolin found in Nepal are generally distributed below 2000 m amsl (Jnawali et al., 2011). The Chinese pangolin has been reported to occupy a wide range of elevations, from as low as <100 m amsl in Taiwan (Republic of China) and up to 3000 m amsl in the Taplejung district of Nepal (Wu et al., 2020). In the Nagarjun forest of Shivapuri Nagarjun National Park, Nepal pangolins were found between an elevation range of 1450–1550 m (Bhandari & Chalise, 2014). Similarly, this species has been recorded at 1300–1700 m amsl in Bhutan (Dorji et al., 2020). However, in our study, there was no significant effect of elevation on burrow distribution. The majority of the burrows were distributed between 450 and 600 m amsl, followed by 601–750 m amsl, and gradually decreased with increasing elevation. The diversity of termites decreases with increasing elevation (Gathorne-Hardy et al., 2001; Hemachandra et al., 2014) and could explain why we observed a slight negative correlation between the number of burrows and elevation. Furthermore, elevation alone does not directly affect the distribution of Chinese pangolins. Instead, elevation is correlated with other climatic predictors, such as precipitation, temperature, and solar radiation (Elith & Leathwick, 2009), that can lead to changes in habitat features and habitat quality, thus influencing species distributions. It should be noted that the elevation range in our study was relatively narrow (450–900 m) and a significant effect may be observed if this range is increased. Thus, further investigation of this parameter is suggested.

Previous studies conducted in the Nagarjun forest revealed that Chinese pangolins prefer south-facing slopes (Acharya, 2001; Gurung, 1996). A study conducted by Dorji et al. (2020) in Bhutan revealed that the Chinese pangolin strongly prefers NE-facing slopes followed by NW-facing slopes. Furthermore, a study conducted by Bhandari and Chalise (2014) in the Nagarjun forest of Shivapuri Nagarjun National Park also found that pangolins prefer NW-facing slopes. Our study generally coincides with the above studies since the majority of burrows were recorded on NW- and SE-facing slopes. A study conducted by Suwal (2011) suggested that the preference for certain aspects might be influenced by climatic conditions, availability of food, and degree of human disturbance.

The majority of burrows recorded in Nepal by Suwal et al. (2020) were found on slopes with 30–50° inclines. Similarly, studies conducted in China found that the

Chinese pangolin preferred varied slope inclines of 30–40° (Wu et al., 2004) and 30–60° (Wu et al., 2003). In contrast, a study conducted in the Nagarjun forest of Shivapuri Nagarjun National Park of Nepal showed that pangolins preferred slope inclines of 20–30° (Bhandari & Chalise, 2014), while in Bhutan the number of Chinese pangolin signs increased between slopes of 0%–25% and gradually decreased after 45% (Dorji et al., 2020) in Bhutan. In our study, the majority of the burrows were recorded between 0% and 30% slope inclines, which coincides with previous studies. A possible explanation could be the presence of clayey loam soil at 0%–45% slopes in the study area, which is suitable for digging.

A previous study reported that the Chinese pangolin mostly preferred a canopy cover of 50%–75% (Suwal et al., 2020), but our study observed the majority of burrows between 26% and 50% canopy cover, which is similar to the results of Bhandari and Chalise (2014) in Nepal, Wu et al. (2003) in China, and Dorji et al. (2020) in Bhutan. A possible explanation may be that areas with more open canopy have a drier forest floor, and the presence of undecomposed leaf litter, dead sticks, and branches in such dry environments increases the number of ants and termites. The occurrence of termites is higher in dry areas than wet areas (Hemachandra et al., 2014). Similarly, in terms of ground cover, Chinese pangolins showed a preference for heavy undergrowth shrub coverage (81%–100%) in Dawuling Natural Reserve, China (Wu et al., 2003) and Dorji et al. (2020) recorded the most burrows in areas with 51%–75% and 76%–100% ground cover in Bhutan, which coincides with our results. Pangolin preference for dense cover may help them hide from predators since they have poor defense mechanisms against predators (Liu & Xu, 1981). The use of dense ground cover by pangolins to conceal their burrow entrance was also reported in the study conducted by Wu et al. (2004).

The presence of water sources also plays a significant role in determining the presence of Chinese pangolins (Katuwal et al., 2017). A study conducted by Shrestha et al. (2021) revealed that most burrows of the Chinese pangolin were within 150 m from a water source. Similarly, a study by Katuwal et al. (2017) revealed that most burrows were recorded within 100–200 m from a source of water. Our results coincide with these two studies, as the number of burrows was higher near water sources. This result is unsurprising given that Chinese pangolins drink water frequently (Suwal, 2011) and burrows are rarely found in drier areas (Bhandari & Chalise, 2014).

A study conducted by Wu et al. (2003) in China suggests that Chinese pangolins prefer to reside far from human disturbance. Peng (2020) also reached similar conclusions recently. In terms of distance to the nearest settlement, a recent study found that most burrows were recorded within 200 m of a settlement (Shrestha et al., 2021), and Katuwal et al. (2017) also reported the presence of Chinese pangolin burrows near settlements. In our study, most burrows were recorded within 0–700 m of a settlement and the number of burrows gradually decreased with greater distance from settlements. One possible explanation is that the loss of natural water sources due to climate change might be driving Chinese pangolins to occupy habitats that are in closer contact with humans. Furthermore, another reason may be that our study was conducted in CFs, and such forests are generally located near villages (Shrestha et al., 2021).

Like our results for distance from nearest settlement, we observed that most burrows were recorded within 0–700 m of a road, and that the number of burrows gradually decreased with increasing distance from the nearest road. These results are similar to a study conducted by Katuwal et al. (2017), where almost all burrows were recorded within 100 m of a road, and the number of burrows decreased as the distance to the nearest road increased. The detection of Chinese pangolins closer to trails and roads may increase their risk of detection by humans and may have negative impacts on this critically endangered species.

In our study, the Chinese pangolin favored areas with ant and termite colonies. High termite richness and abundance are predicted to favor the presence of pangolins (Swart et al., 1999). Moreover, Chinese pangolins utilize a wide range of habitats including primary and secondary tropical forest, limestone forest, bamboo forest, grassland, and agricultural lands (Gurung, 1996; Katuwal et al., 2017; Suwal, 2011). A study conducted in Bangladesh revealed that pangolins utilized mixed evergreen and dry deciduous forests (Trageser et al., 2017). In our study, Chinese pangolin burrows were mainly distributed in forested areas followed by agricultural land, and the study of Suwal et al. (2020) reported similar findings, as they recorded 74% of burrows in mixed forest areas containing *S. robusta*, *S. wallichii*, and *C. indica*. In our study, we also found that the majority of burrows were encountered in red soil followed by brown soil. A possible explanation may be that red soil is acidic in nature (Shen et al., 2013) and most termites prefer soil conditions ranging from acidic to slightly basic (3.5–8.7 pH; Li et al., 2017).

Finally, Chinese pangolins in our study area appeared to prefer habitats dominated by *S. robusta*, *S. wallichii*, *I. cylindrical*, and *C. dactylon* followed by habitats dominated by *S. wallichii*, *C. indica*, *N. auriculata*, and *I. cylindrical*, which is similar to the study conducted by Bhandari and Chalise (2014) in the Nagarjun forest of

Shivapuri Nagarjun National Park in Nepal. The elevational gradient of Nepal contributes to diverse vegetation compositions consisting of various herb, shrub, and tree species (Suwal et al., 2020), which may influence the activities of burrowing mammals such as pangolins. Better management of vegetation in CFs and similar environments could provide additional suitable habitat for pangolins. Thus, to help species conservation, it is necessary to prioritize community-based conservation initiatives.

CONCLUSION

In this study, we document the current distribution pattern, burrow density status, and habitat preference of the Chinese pangolin. The distribution was found to be clumped with 1.04 active burrows/ha and appears to be influenced by different habitat factors such as aspect; slope; canopy cover; ground cover; distances to the nearest water source, settlement, and road; presence of ant and termite colonies; habitat type and soil type. The study area currently provides favorable habitat for Chinese pangolins and requires regular monitoring and habitat management through community involvement for the long-term conservation of this species and their preferred habitats.

AUTHOR CONTRIBUTIONS

Bijaya Dhami: Conceptualization (lead); data curation (lead); formal analysis (lead); writing original draft (lead); writing—review and editing (lead). Bijaya Neupane and Bishnu Prasad Devkota: Formal analysis (equal); writing original draft (equal); writing—review and editing (equal). Tek Maraseni, Bipana Maiya Sadadev, Shreyashi Bista, Amit Adhikari, Nar Bahadur Chhetri, Melina Panta, and Alyssa B. Stewart: Writing—review and editing (equal).

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data are sensitive and cannot be provided publicly as the species is critically endangered and availability of data publicly may lead to poaching of the species. Qualified researchers may request access to the data from Bijaya Dhami (bijaysinghdhami@gmail.com).

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REFERENCES

Aarts, G., M. MacKenzie, B. McConnell, M. Fedak, and J. Matthiopoulos. 2008. "Estimating Space-Use and Habitat Preference from Wildlife Telemetry Data." *Ecography* 31: 140–60. https://doi.org/10.1111/j.2007.0906-7590.05236.x.

Acharya, P. M. 2001. "Status and Distribution of Pangolin in the Nagarjun Forest in Central Nepal." Workshop on Asian Pangolin, Taipei, Taiwan. December 17–18.

Acharya, S., H. P. Sharma, R. Bhattarai, B. Poudyal, S. Sharma, and S. Upadhaya. 2021. "Distribution and Habitat Preferences of the Chinese Pangolin *Manis pentadactyla* (Mammalia: Manidae) in the Mid-Hills of Nepal." *Journal of Threatened Taxa* 13: 18959–66. https://doi.org/10.11609/jott.3952.13.8.18959-18966.

Aryal, C. M., and N. Poudel. 2018. "Habitat Features Associated with Chinese Pangolin Distribution in Nagarjun and Ranibari Forests, Kathmandu, Nepal." *Goldengate Journal of Science & Technology* 4: 62–8.

ASF. 2021. "Alaska Satellite Facility (ASF)." https://search.asf.alaska.edu/#/.

Bajaj, S., and D. G. B. Amali. 2019. "Species Environmental Niche Distribution Modeling for *Panthera tigris tigris* 'Royal Bengal Tiger' Using Machine Learning." In *Emerging Research in Computing, Information, Communication and Applications* 251–63. Singapore: Springer. https://doi.org/10.1007/978-981-13-5953-8_22.

Balakrishnan, M., and P. S. Easa. 1986. "Habitat Preferences of the Larger Mammals in the Parambikulam Wildlife Sanctuary, Kerala, India." *Biological Conservation* 37: 191–200. https://doi.org/10.1016/0006-3207(86)90081-9.

Baral, H. S., and K. B. Shah. 2008. *Wild Mammals of Nepal*. Kathmandu: Himalayan Nature.

Bashyal, A., N. Shrestha, A. Dhakal, S. N. Khanal, and S. Shrestha. 2021. "Illegal Trade in Pangolins in Nepal: Extent and

Network." *Global Ecology and Conservation* 32: e01940. https://doi.org/10.1016/j.gecco.2021.e01940.

Bhandari, N. 2013. *Distribution, Habitat Utilization and Threats Assessment of Chinese Pangolin (Manis pentadactyla Linnaeus, 1758) in Nagarjun Forest of Shivapuri Nagarjun National Park*. Kathmandu: Central Department of Zoology, Tribhuvan University.

Bhandari, N., and M. K. Chalise. 2014. "Habitat and Distribution of Chinese Pangolin (*Manis pentadactyla* Linnaeus, 1758) in Nagarjun Forest of Shivapuri Nagarjun National Park, Nepal." *Nepalese Journal of Zoology* 2: 18–25.

Boomsma, A. 2014. *Regression Diagnostics with R*. Groninga: Department of Statistics & Measurement Theory, University of Groningen.

Bowerman, B. L., and R. T. O'connell. 1990. *Linear Statistical Models: An Applied Approach*. Monterey, CA: Brooks/Cole.

Büchi, L., and S. Vuilleumier. 2014. "Coexistence of Specialist and Generalist Species Is Shaped by Dispersal and Environmental Factors." *The American Naturalist* 183: 612–24. https://doi.org/10.1086/675756.

Challender, D., S. Wu, P. Kaspal, A. Khatiwada, A. Ghose, N. Ching-Min Sun, R. K. Mohapatra, et al. 2019. "*Manis pentadactyla* (Errata Version Published in 2020)." IUCN Red List of Threatened Species 2019 e.T12764A168392151 8235. https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T12764A168392151.en.

CITES. 2020. "CITES Appendices I, II, and III." 28 August 2020. 74 pp. https://cites.org/sites/default/files/eng/app/2020/E-Appendices-2020-08-28.pdf.

Corbet, G. B., and J. E. Hill. 1992. *The Mammals of the Indomalayan Region: A Systematic Review*. Oxford: Oxford University Press.

Dhital, S., S. Mani, S. Thapa, W. V. Bleisch, A. Shrestha, and N. P. Koju. 2020. "Distribution of Chinese Pangolin (*Manis pentadactyla*) in Nagarjun Forest of Shivapuri Nagarjun National Park, Nepal." *Nepalese Journal of Zoology* 4: 1–7. https://doi.org/10.3126/njz.v4i1.30667.

DNPWC. 2018. *Pangolin Conservation Action Plan for Nepal (2018–2022)*. Kathmandu: Department of National Park and Wildlife Conservation.

DNPWC. 2019. *Pangolin Monitoring Guideline for Nepal*. Kathmandu: Department of National Parks and Wildlife Conservation, Ministry of Forests and Environment, 48 pp.

DNPWC. 2022. "Department of National Parks and Wildlife Conservation." https://dnpwc.gov.np/en/species-detail/55/#:~:text=There%20is%20very%20little%20information,observed%20to%20be%20in%20decline.

Dorji, D., J. L. Chong, and T. Dorji. 2020. "Habitat Preference and Current Distribution of Chinese Pangolin (*Manis pentadactyla* L. 1758) in Dorokha Dungkhag, Samtse, Southern Bhutan." *Journal of Threatened Taxa* 12: 16424–33. https://doi.org/10.11609/jott.5839.12.11.16424-16433.

Elith, J., and J. R. Leathwick. 2009. "Species Distribution Models: Ecological Explanation and Prediction across Space and Time." *Annual Review of Ecology, Evolution, and Systematics* 40: 677–97.

Gathorne-Hardy, F., Syaukani, and P. Eggleton. 2001. "The Effects of Altitude and Rainfall on the Composition of the Termites (Isoptera) of the Leuser Ecosystem (Sumatra, Indonesia)." *Journal of Tropical Ecology* 17(3): 379–93. https://doi.org/10.1017/S0266467401001262.

Ghimire, P., N. Raut, P. Khanal, S. Acharya, and S. Upadhaya. 2020. "Species in Peril: Assessing the Status of the Trade in Pangolins in Nepal." *Journal of Threatened Taxa* 12: 15776–83. https://doi.org/10.11609/jott.5698.12.8.15776-15783.

GoN. 1973. *National Parks and Wildlife Conservation Act*. Kathmandu: Government of Nepal, Nepal Law Commission.

GoN. 2019. *Forest Act (Second Amendment)*. Kathmandu: Government of Nepal, Nepal Law Commission.

Gurung, J. B. 1996. "A Pangolin Survey in Royal Nagarjung Forest in Kathmandu, Nepal." *Tigerpaper* 23: 29–32.

Heinrich, S., T. A. Wittman, J. V. Ross, C. R. Shepherd, D. W. S. Challender, and P. Cassey. 2017. "The Global Trafficking of Pangolin: A Comprehensive Summary of Seizures and Trafficking Routes from 2010-2015." http://static1.1.sqspcdn.com/static/f/157301/27779360/1513337200303/global-pangolin-assessment.pdf.

Hemachandra, I. I., J. P. Edirisinghe, W. A. I. P. Karunaratne, C. V. S. Gunatilleke, and R. H. S. S. Fernando. 2014. "Diversity and Distribution of Termite Assemblages in Montane Forests in the Knuckles Region, Sri Lanka." *International Journal of Tropical Insect Science* 34(1): 41–52. https://doi.org/10.1017/S174275841300043X.

Hodgson, B. H. 1836. "Synoptical Description of Sundry New Animals, Enumerated in the Catalogue of Nipálese Mammals." *Journal of the Asiatic Society of Bengal* 5: 231–8.

Ingram, D. J., D. Willcox, and D. W. S. Challender. 2019. "Evaluation of Applied Methods to Detect and Monitor Selected Mammalian Taxa and Its Application to Pangolin Conservation." *Global Ecology and Conservation* 18: e00632.

Jnawali, S. R., H. S. Baral, S. Lee, K. P. Acharya, G. P. Upadhyay, M. Pandey, R. Shrestha, et al. 2011. "The Status of Nepal's Mammals: The National Red List Series-IUCN." 266 pp. https://www.yumpu.com/en/document/view/17024247.

Kaspal, P. 2008. *Status, Distribution, Habitat Utilization and Conservation of Chinese Pangolin in the Community Forests of Suryabinayak Range Post, Bhaktapur District*. Bhaktapur: Khowpa College (TU Affiliated).

Katuwal, H. B., K. R. Neupane, D. Adhikari, M. Sharma, and S. Thapa. 2015. "Pangolins in Eastern Nepal: Trade and Ethno-Medicinal Importance." *Journal of Threatened Taxa* 7: 7563–7. https://doi.org/10.11609/JoTT.o4202.7563-7.

Katuwal, H. B., H. P. Sharma, and K. Parajuli. 2017. "Anthropogenic Impacts on the Occurrence of the Critically Endangered Chinese Pangolin (*Manis pentadactyla*) in Nepal." *Journal of Mammalogy* 98: 1667–73. https://doi.org/10.1093/jmammal/gyx114.

Li, Y., Z. Y. Dong, D. Z. Pan, C. Z. Pan, and L. H. Chen. 2017. "Effects of Termites on Soil pH and Its Application for Termite Control in Zhejiang Province, China." *Sociobiology* 64: 317–26. https://doi.org/10.13102/sociobiology.v64i3.1674.

Lin, J. S. 2011. "Home Range and Burrow Utilization in Formosan Pangolins (*Manis pentadactyla pentadactyla*) at Luanshan, Taitung." Doctoral diss., MSc thesis, National Pingtung University of Science and Technology.

Liu, Z. H., and L. H. Xu. 1981. "Pangolin's Habits and Its Resource Protection." *Chinese Journal of Zoology* 16: 40–1.

Mattos, I. d., B. Zimbres, and J. Marinho-Filho. 2021. "Habitat Specificity Modulates the Response of Small Mammals to Habitat Fragmentation, Loss, and Quality in a Neotropical Savanna." *Frontiers in Ecology and Evolution* 9: 751315. https://doi.org/10.3389/fevo.2021.751315.

Montgomery, D. C., E. A. Peck, and G. G. Vining. 1982. *Introduction to Linear Regression Analysis*. Hoboken, NJ: John Wiley & Sons.

Neupane, B., B. Dhami, S. Bista, B. M. Sadadev, S. Regmi, S. Shrestha, B. Shrestha, I. Traxmandlova, S. Varachova, and P. Kindlmann. 2022. "Ecological Factors Determining Barking Deer Distribution and Habitat Use in the Mid-Hills of Nepal." *Frontiers in Ecology and Evolution* 10: 894369. https://doi.org/10.3389/fevo.2022.894369.

Newton, P., N. Van Thai, S. Roberton, and D. Bell. 2008. "Pangolins in Peril: Using Local Hunters' Knowledge to Conserve Elusive Species in Vietnam." *Endangered Species Research* 6: 41–53. https://doi.org/10.3354/esr00127.

Odum, E. P. 1971. *Fundamentals of Ecology* 205–7. Philadelphia, PA: W.B. Sanders Company.

OSM. 2021. "Open Street Map." https://www.openstreetmap.org/.

Pandey, H. P., and N. P. Pokhrel. 2021. "Formation Trend Analysis and Gender Inclusion in Community Forests of Nepal." *Trees, Forests and People* 5: 100106. https://doi.org/10.1016/j.tfp.2021.100106.

Peng, J. 2020. "Study on the Ecological Geographical Distribution, Habitat Selection and Wild Resources of *Manis pentadactyla*." MSc thesis, Chongqing Normal University.

Pereira, H. M., G. C. Daily, and J. Roughgarden. 2004. "A Framework for Assessing the Relative Vulnerability of Species to Land-Use Change." *Ecological Applications* 14: 730–42. https://doi.org/10.1890/02-5405.

R Core Team. 2020. *R: A Language and Environment for Statistical Computing*. Vienna: R Foundation for Statistical Computing.

Rai, A., S. Sharma, S. Shrestha, A. Bashyal, S. Shrestha, and S. N. Khanal. 2019. "Habitat Analysis and Distribution of Chinese Pangolin in Community Forests of Dolakha District, Nepal." In *Conference Proceedings of International Conference on Natural Resources, Agriculture and Society in Changing Climate (NRACC)-2019* Kathmandu, 17–19 August, 2019, 161–74.

Safford, R. K. 2004. "Modelling Critical Winter Habitat of Four Ungulate Species in the Robson Valley, British Columbia." *Journal of Ecosystems & Management* 4: 1–14. https://doi.org/10.22230/jem.2004v4n2a275.

Sanusi, M. A., M. A. Shukor, W. A. Wan Julian, and C. Traeholt. 2013. "Activity Pattern of Selected Ungulates at Krau Wildlife Reserve." *AIP Conference Proceedings* 1571: 325–30. https://doi.org/10.1063/1.4858677.

Sapkota, R. 2016. "Habitat Preference and Burrowing Habits of Chinese Pangolin: A Case from Shivapuri and Nagarjun National of Nepal." Doctoral diss., Tribhuvan University.

Schemnitz, S. D. 1980. *Wildlife Management Techniques Manual*, 4th Ed. Washington, DC: The Wildlife Society.

Sharma, H. P., B. Rimal, M. Zhang, S. Sharma, L. P. Poudyal, S. Maharjan, R. Kunwar, et al. 2020. "Potential Distribution of the Critically Endangered Chinese Pangolin (*Manis pentadactyla*) in Different Land Covers of Nepal: Implications for Conservation." *Sustainability* 12(3): 1282. https://doi.org/10.3390/su12031282.

Sharma, S., H. P. Sharma, C. Chaulagain, H. B. Katuwal, and J. L. Belant. 2020. "Estimating Occupancy of Chinese Pangolin (*Manis pentadactyla*) in a Protected and Non-protected Area of Nepal." *Ecology and Evolution* 10: 4303–13. https://doi.org/10.1002/ece3.6198.

Sharma, S., H. P. Sharma, H. B. Katuwal, C. Chaulagain, and J. L. Belant. 2020. "People's Knowledge of Illegal Chinese Pangolin Trade Routes in Central Nepal." *Sustainability* 12(12): 4900. https://doi.org/10.3390/su12124900.

Shen, J. P., P. Cao, H. W. Hu, and J. Z. He. 2013. "Differential Response of Archaeal Groups to Land Use Change in an Acidic Red Soil." *Science of the Total Environment* 461–462: 742–9. https://doi.org/10.1016/j.scitotenv.2013.05.070.

Shrestha, B., and K. Basnet. 2005. "Indirect Methods of Identifying Mammals: A Case Study from Shivapuri National Park, Nepal." *Ecoprint: An International Journal of Ecology* 12: 43–57. https://doi.org/10.3126/eco.v12i0.3196.

Shrestha, S., A. Bashyal, R. Rijal, J. Shrestha, P. Shrestha, N. Shrestha, T. J. McGreevy Jr, B. Buffum, and S. N. Khanal. 2021. "An Ecological Assessment of Critically Endangered Chinese Pangolin *Manis pentadactyla* (Mammalia: Pholidota: Manidae) in the Midhills Region of Nepal." *Open Journal of Ecology* 11: 344–56. https://doi.org/10.4236/oje.2021.114024.

Smith, R. L. 1980. *Ecology and Field Biology*. New York: Harper & Row.

Suwal, R. N., W. J. M. Verheugt, and P. Yonzon. 1995. *Enumeration of the Mammals of Nepal*. Arnhem: Euroconsult.

Suwal, T. L. 2011. "Status, Distribution, Behaviour and Conservation of Pangolins in Private and Community Forest of Balthali in Kavre, Nepal." MSc thesis, Central Department of Zoology, Tribhuvan University.

Suwal, T. L., A. Thapa, S. Gurung, P. C. Aryal, H. Basnet, K. Basnet, K. B. Shah, et al. 2020. "Predicting the Potential Distribution and Habitat Variables Associated with Pangolins in Nepal." *Global Ecology and Conservation* 23: e01049. https://doi.org/10.1016/j.gecco.2020.e01049.

Swart, J. M., P. R. K. Richardson, and J. W. H. Ferguson. 1999. "Ecological Factors Affecting the Feeding Behaviour of Pangolins (*Manis temminckii*)." *Journal of Zoology* 247: 281–92. https://doi.org/10.1111/j.1469-7998.1999.tb00992.x.

Thapa, P. 2013. "An Overview of Chinese Pangolin (*Manis pentadactyla*): Its General Biology, Status, Distribution and Conservation Threats in Nepal." *The Initiation* 5: 164–70.

Thapa, P., A. P. Khatiwada, S. C. Nepali, and S. Paudel. 2014. "Distribution and Conservation Status of Chinese Pangolin (*Manis pentadactyla*) in Nangkholyang VDC, Taplejung, Eastern Nepal." *American Journal of Zoological Research* 2: 16–21. https://doi.org/10.12691/ajzr-2-1-3.

Trageser, S. J., A. Ghose, M. Faisal, P. Mro, P. Mro, and S. C. Rahman. 2017. "Pangolin Distribution and Conservation Status in Bangladesh." *PLoS One* 12: e0175450. https://doi.org/10.1371/journal.pone.0175450.

USGS. 2021. "Earth Explorer." https://earthexplorer.usgs.gov/.

Willcox, D., H. C. Nash, S. Trageser, H. J. Kim, L. Hywood, E. Connelly, G. Ichu Ichu, et al. 2019. "Evaluating Methods for Detecting and Monitoring Pangolin (Pholidata: Manidae) Populations." *Global Ecology and Conservation* 17: e00539. https://doi.org/10.1016/j.gecco.2019.e00539.

Wilson, G. J., and R. J. Delahay. 2001. "A Review of Methods to Estimate the Abundance of Terrestrial Carnivores Using Field Signs and Observation." *Wildlife Research* 28: 151–64. https://doi.org/10.1071/WR00033.

Wu, S., G. Ma, H. Chen, Z. Xu, Y. Li, and N. Liu. 2004. "A Preliminary Study on Burrow Ecology of *Manis pentadactyla*." *The Journal of Applied Ecology* 15: 401–7.

Wu, S., N. C. M. Sun, F. Zhang, Y. Yu, G. Ades, T. L. Suwal, and Z. Jiang. 2020. "Chinese Pangolin *Manis pentadactyla* (Linnaeus, 1758)." In *Pangolins,* edited by D. W. S. Challender, H. C. Nash, and C. Waterman, 49–70. London: Elsevier Academic Press. https://doi.org/10.1016/B978-0-12-815507-3.00004-6.

Wu, S. B., N. F. Liu, G. Z. Ma, Z. R. Xu, and H. Chen. 2003. "Habitat Selection by Chinese Pangolin (*Manis pentadactyla*) in Winter in Dawuling Natural Reserve." *Mammalia* 67(4): 493–502. https://doi.org/10.1515/mamm-2003-0403.

Wu, S. B., G. Z. Ma, Q. X. Liao, and K. H. Lu. 2005. *Studies of Conservation Biology on Chinese Pangolin (Manis pentadactyla)*. Beijing: Chinese Forest Press.

Zhang, M., A. Gouveia, T. Qin, R. Quan, and V. Nijman. 2017. "Illegal Pangolin Trade in Northernmost Myanmar and Its Links to India and China." *Global Ecology and Conservation* 10: 23–31. https://doi.org/10.1016/j.gecco.2017.01.006.

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