FAUNAL COMPOSITION IN THE DIET AND FACTORS AFFECTING THE FORAGING HABITAT OF THE CHINESE PANGOLIN (*Manis pentadactyla*) IN CHANDRAGIRI MUNICIPALITY, KATHMANDU, NEPAL

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Submitted to

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DECLARATION

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

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This is to recommend that the thesis entitled "Faunal composition in the diet and factors affecting the foraging habitat of the Chinese Pangolin (*Manis pentadactyla*) in Chandragiri Municipality, Kathmandu, Nepal" has been carried out by Ms. Sharmila Tamang for the partial fulfilment of the degree of Master of Science in Zoology with special paper Ecology and Environment. This is her original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institutions.

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CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Ms. Sharmila Tamang entitled "Faunal composition in the diet and factors affecting the foraging habitat of the Chinese Pangolin (*Manis pentadactyla*) in Chandragiri Municipality, Kathmandu, Nepal" has been accepted as a partial fulfilment for the requirements of the degree of Master of Science in Zoology with special paper Ecology and Environment.

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LIST OF ABBREVIATIONS

Abbreviated form	Details of Abbreviations
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
DBH	Diameter at Breast Height
GPS	Global Positioning System
IUCN	International Union for Conservation of Nature
IVI	Importance Value Index
Mya	Million years ago
PA	Protected Area

ABSTRACT

The Chinese Pangolin is one of the critically endangered mammalian species, and its population is declining due to illegal hunting and poaching, deforestation, fires, and habitat destruction. It is a nocturnal and shy animal, which survives at the highly specialized diets of ants and termites. Limited knowledge is available on the diet and foraging habitat of this species, therefore this study investigated its major faunal diets and foraging habitat utilization in Chandragiri Municipality of Kathmandu, Nepal. The faunal diet of the Chinese Pangolin was identified through fecal analysis. Major ant prey species for Chinese Pangolin in the study area were *Aphaenogaster symthiesii*, *Camponotus* sp., *Monomorium* sp., and *Pheidole* sp. The foraging habitat was assessed by the presence and absence of Chinese Pangolin's sign. A total of 99 Chinese pangolin's burrows including 11 new and 88 foraging burrows were recorded during the study period. The burrows were not uniformly distributed and recorded mostly in dense forest cover with dominant tree species like *Schima wallichii*, *Myrica esculenta*, *Castonopsis tribuloides*, *Pinus roxburghii*, and *Cleyera* sp. The foraging burrows were observed between 1,500–1,700 m of elevation in slopes of 20–40°. The majority of foraging burrows were recorded under the dense forest canopy coverage of 50–75% in the Southeast and South aspect. The Chinese Pangolin's occurrence were affected by the slope and distance to ant nests, and agricultural lands. The data generated from this study on diet and foraging habitat can be used for developing a site specific management plan for the Chinese Pangolin outside the protected area system of Nepal.

1. INTRODUCTION

1.1 Background of the study

The diet composition of species provides insights into not only the food preferences and availability but also the behavior, foraging ecology and habitat use (Challender 2009), and season and opportunity of a species (Zweifel-Schielly et al. 2012). Knowledge on species' diet is essential to developing conservation action and management plans for their long-term persistence (Redford 1986, Challender 2009). It also aids in understanding the interactions among the species and their impacts on prey species (Klare et al. 2011). The herbivore diet particularly gives insight into ecological and evolutionary processes like habitat selection, competitive interactions (e.g., coevolution of primary producers), and body condition in different environments (Krebs 1998). However, carnivore diets depend on the diversity, abundance, and availability of prey resources that vary in space or time, and also are affected by competitive interactions with sympatric carnivore species indicating resource competition (Andheria et al. 2007, Andersen et al. 2017), and potentially disease transmission (Sharma and Achhami 2022).

A large number and variety of ants and termites are the major food sources for a wide range of predatory mammals (Redford 1983). All the tropics have the highest population of ants and termites, and each tropical area has its own distinct and unique species of anteaters. Most mammals that eat huge amounts of ants also eat termites, as they are specialized in the prey of a specific type, as small, fairly homogeneous, social arthropods rather than a specific taxonomy (Redford 1983). Approximately, 216 animal species are known to consume ants or termites, which include opportunistic myrmecophages such as mongooses, badgers, bears, etc. and about 12% are specialized obligate myrmecophagous mammals such as pangolins, armadillos, anteaters, aardvarks, and aardwolves (Redford 1987). Knowledge of dietary components in myrmecophagous mammals is not only helpful in understanding their influence on ants and termite populations but also in their ecology, predicting their effect on the dynamics of prey populations and the role of prey-predators in the ecosystem (Oli 1993, Klare et al. 2011).

The Chinese Pangolin (*Manis pentadactyla* Linnaeus, 1758) is one of the two species of pangolins found in Nepal (Baral and Shah 2008, Jnawali et al. 2011). It is one of the four Asian species representing the intermediate form between the Malayan and Indian

Pangolins (Pocock 1924). The Chinese Pangolin is distributed in South-Eastern regions of Asia including Nepal (Challender et al. 2019). In Nepal, it is distributed in Eastern, Central, and Western Nepal (Shrestha 2003). It is found in Taplejung, Illam, Panchthar, Sindhuli, Dhading, Kavre, Ramechhap, Panauti, Annapurna Conservation Area, Makalu-Barun Conservation Area, Nagarjun, Barabise, Kathmandu, Bhaktapur, Gorkha, and Bardia (Challender et al. 2019, Sharma et al. 2020a). It is widely distributed in primary and secondary tropical forests (Chakraborty et al. 2002), limestone forests, bamboo forests, grasslands, and agricultural fields (DNPWC and DoF 2018, Suwal et al. 2020, Sharma et al. 2020b). The distribution of the pangolin is mainly affected by factors such as elevation, slope, aspect, canopy coverage, vegetation, food availability, and distance from the nearest roads, water sources, agricultural lands, and human settlements (Dorji et al. 2020, Suwal et al. 2020, Sharma et al. 2020c, Acharya et al. 2021).

The Chinese Pangolin belongs to the susceptible species due to its taxonomic uniqueness (monotypic order: Pholidota), food specialization and stenophagy (eating only ants and termites), low reproductive rate (one or two cub per year), poor self-defensive mechanism, and strict requirement for habitat (Wu et al. 2004a). It has been listed as the Critically Endangered species in the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (Challender et al. 2019). It is listed under Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2022) and protected in Nepal under the National Parks and Wildlife Conservation (NPWC) Act 1973 (Jnawali et al. 2011). It is facing a very high risk of extinction in the wild because of its illegal hunting and poaching (Challender et al. 2019) for its flesh and scales, mining, grazing, forest fires, deforestation, and habitat destruction (Gurung 1996, Chao et al. 2005, Sharma et al. 2020c). The conservation of pangolin would play an important role in maintaining the ecosystem by regulating insect populations (Challender et al. 2019, Sharma et al. 2020c). It also controls the economic loss caused by termites and ants to crops and improves the quality of the soil (Chao et al. 2020).

Pangolin is one of the Myrmecophagous mammal species (Redford 1983), with only a few developing specialized anatomical and morphological adaptations due to chitinous parts of termites, and ants (Jacobsen et al. 1991, Delsuc et al. 2014, Pietersen et al. 2016a, Sun et al. 2020a), and adapted to a specialized diet of ants, termites and variety of small insect species (Newton 2007, Irshad et al. 2015). Because of their unique adaptation to digging burrows to feed, shelter, and breed (Heath and Coulson 1997, Bruce et al. 2018), it is complex or challenging to study their behavior directly in the field. In addition, the specialist diet makes them extremely difficult to maintain in captivity as they often reject unfamiliar insect species or become ill when fed foreign food (Yang et al. 2007). There is limited study on the diet and feeding ecology of the pangolin, probably due to the low chance of obtaining feces for analysis. Hence this study provides some information on the faunal dietary composition of the Chinese Pangolin, which can help to develop pangolin conservation programs by understanding their foraging habits and habitat use through knowledge of their prey species' information.

1.2 Objectives

1.2.1 General objective

The general objective of the study was to assess the faunal dietary composition of the Chinese Pangolin in foraging habitat in Chandragiri Municipality, Kathmandu, Nepal.

1.2.2 Specific objectives

i. To identify the prey species ingested by the Chinese Pangolin.

ii. To assess the foraging habitat used by the Chinese Pangolin.

1.3 Significance of the study

There are only limited scientific studies on the Chinese Pangolins and they are mainly conducted on their status, distribution, and abundance within Nepal’s protected areas (PAs). Recent surveys have reported the occurrence of Chinese Pangolins in 27 out of 77 districts of Nepal (DNPWC and DoF 2018), and most of the potential habitat is ranged in the mid-hill regions in both forest and agricultural lands (Sharma et al. 2020a). The pangolin plays an important role in maintaining a balanced ecosystem by controlling the population of insects such as ants and termites in its habitat as well as the agricultural lands as a biological control agent (Chao et al. 2020). Its feeding ecology helps in understanding the feeding behavior, prey choice, and the foraging habitat. The information on the diet can also be applied to the conservation of both wild and captive populations of the Chinese Pangolins. However, little information is available on the feeding ecology and diet of pangolins in Nepal till now. Scarce and limited studies on the diets of the Chinese Pangolins have been recorded from other range countries. This lack of sufficient data has led to difficulty in captive rearing of the pangolins because of insufficient supply of natural foods such as ants and termites as they are selective feeders, as well as protection in their natural habitat due to the destruction of the foraging habitats. Therefore, the study of diet of the pangolin is very important as it helps to confirm the specific ant and termite species preferred by the Chinese Pangolin and their foraging habitats. The data generated in this study can help in formulating the strategies and plans in conservation, and increment of the populations of the species for in-situ conservation programs.

2. LITERATURE REVIEW

2.1 Chinese Pangolin, *Manis pentadactyla* Linnaeus, 1758

Pangolins are small mammals native to Asia and Africa. The word "Pangolin" is derived from the Malayan phrase "Pen gulling" which denotes the ability of the animal to curl up into a ball. They are commonly known as the scaly ant eaters due to their bodies covered by overlapping scales and food habits of feeding exclusively on ants and termites. There are only eight extant species; four species each in Asia and Africa (Heighton and Gaubert 2021). The four African species include the White-bellied Pangolin (*Phataginus tricuspis*), the Giant Pangolin (*Smutsia gigantea*), Temmincks Pangolin (*S. temminckii*), and the Black-bellied Pangolin (*P. tetradactyla*) and the four Asian Pangolins are the Sunda Pangolin (*M. javanica*), the Chinese Pangolin (*M. pentadactyla*), the Indian Pangolin (*M. crassicaudata*), and the Philippine Pangolin (*M. culionensis*).

The Chinese Pangolin represents the intermediate form between the Malayan and Indian Pangolins (Pocock 1924), and belong to the order Pholidota, family Manidae, and genus *Manis* (IUCN Pangolin Specialist Group 2022). The term Pholidota is derived from the Greek word “Pholis” or “Pholidos” which means a horny scale. The genus name *Manis* is derived from the Latin word “Manes” meaning ghosts or dead people's spirits referring to its nocturnal behavior and unique appearance. Similarly the species name *pentadactyla* refers to five digits in the fore and hind limbs of the pangolin. It is a shy, nocturnal, elusive, non-aggressive, solitary, insectivorous, and burrowing mammal protected both on the national and international levels (Gaubert 2011).

2.2 Evolution and origin of Pangolins

Pangolins have a long and complex evolutionary history. According to early fossil records, they first appeared just after stegosaurids went extinct more than 66 million years ago (mya) (Norman 1985). The Pholidota is most likely to have originated in Laurasia during the Eocene, given that the oldest fossil pangolins come from Europe along with the two possible closest relatives of Pholidota; Palaeanodonta and Carnivora (Gaudin et al. 2016). Pangolins are nested within Laurasiatheria and Scrotifera and are considered as the sister group to carnivore after repeated DNA test (Murphy et al. 2007). It is hypothesized that later in the Cenozoic, pangolins dispersed from Europe into Africa and Asia, and as a result of global cooling during the Pliocene and Pleistocene, current pangolins are only found in the tropics (Gaudin et al. 2009, Gaubert et al. 2018). The "filter-routes" that connected Africa and Eurasia over the Tethys Seaway during the Upper Eocene (Sen 2013), and the collision of the Arabian micro-plate; the "Gomphotherium landbridge" 16–20 mya (Koufos et al. 2005) may had created the possible dispersion of pangolins between Eurasia and Africa. South Asia and the East Indies did not have fossil pangolins until the Pleistocene. (Emry and Skinner 1970). Based on fossil evidence, the ancestors of current pangolins first lived in Europe before dispersing to Sub-Saharan Africa and eventually to southern Asia (Gaudin et al. 2009).

2.3 Biology and life history

The Chinese Pangolin is a small to medium-sized mammal with a body weight of 3–8 kg. It has a total body length of 89 cm and a tail length of about 40 cm (Wu et al. 2004b, Wu et al. 2020). The tail is shorter with a naked tip but prehensile, which helps the pangolin to hang in the tree branches and also carry the young ones. Male Chinese Pangolin is larger and up to 50% heavier than females. It has a small, narrow mouth, and a stout head. The body is streamlined, elongated, and covered with keratinous scales that act as body armor (Heath 1992). The thick bristle-like hairs grow at the base of the scales. The eyes are protected by thick, heavy eyelids, and the nostrils are naked, moist and pink (Pocock 1924). It has the most well-developed and large ear pinna among all the pangolin species. The tongue is long with a length of up to 40 cm and coated by tenacious saliva, providing a sticky function to efficiently take up as many ants as possible (Heath 1992). It has no teeth or chewing muscles and the oral cavity is small. The stomach is divided into two chambers: the first is a storage chamber that takes up 80% of the total capacity, and the second is a grinding compartment that performs the mastication function (Lin et al. 2015). Large ear pinna, a more thickly set body, and noticeably shorter tail, long claws on the forelimbs, post-anal depression in the skin, and a narrowing near the distal end of the tail help to distinguish the Chinese Pangolin from other Asian Pangolins (Pocock 1924).

Male and female Chinese Pangolins are sexually dimorphic. Individuals are mostly solitary, and they only mate when females are in estrus during a particular breeding season. Mating takes place in the spring and summer (February and July), with females giving birth in the autumn or early spring (September and February) (Heath 1992, Chin et al. 2012, Zhang et al. 2016, Sun et al. 2021). The male pangolins fight each other during mating season, with the winner mating with a female pangolin. The Chinese Pangolin's gestation period lasts between 318 and 372 days, during which the females gradually put on weight and their mammary glands swell (Heath and Vanderlip 1988, Chin et al. 2012, Zhang et al. 2016). The female gives birth to a single offspring at a time; twins are rare (Shibao 1998). Females give birth in a burrow. The infants are born with scales, which harden after two days. The scales are gray or purplish-brown in color, with a darker base, and they are tightly linked to the skin (Zhang et al. 2016). The infant has open eyes and good motor coordination. At birth, the young weigh 80–180 gm and are 185–265 mm in length (Heath and Vanderlip 1988, Chin et al. 2012, Zhang et al. 2016). The mother carries the infants on her back or tail, and if they feel threatened, she immediately folds her baby onto her belly with the help of her tail (Sun et al. 2018). The young begin digging and licking away from the burrow on their own around 11 weeks, and after 15 weeks, they spend a significantly greater amount of time and space exploring (Heath 1992, Sun et al. 2018). Females acquire sexual maturity at the age of 1–1.5 years, while some may reach it as early as 6 months, and can become pregnant with a weight of 2–3 kg (Chin et al. 2012, Zhang et al. 2016).

2.4 Distribution

The Chinese Pangolin is widely distributed from the Eastern to Southern parts of Asia. It is found in Bangladesh, Bhutan, China, Hong Kong, India, Lao People's Democratic Republic, Myanmar, Nepal, Taiwan, Thailand, and Vietnam (Challender et al. 2019).

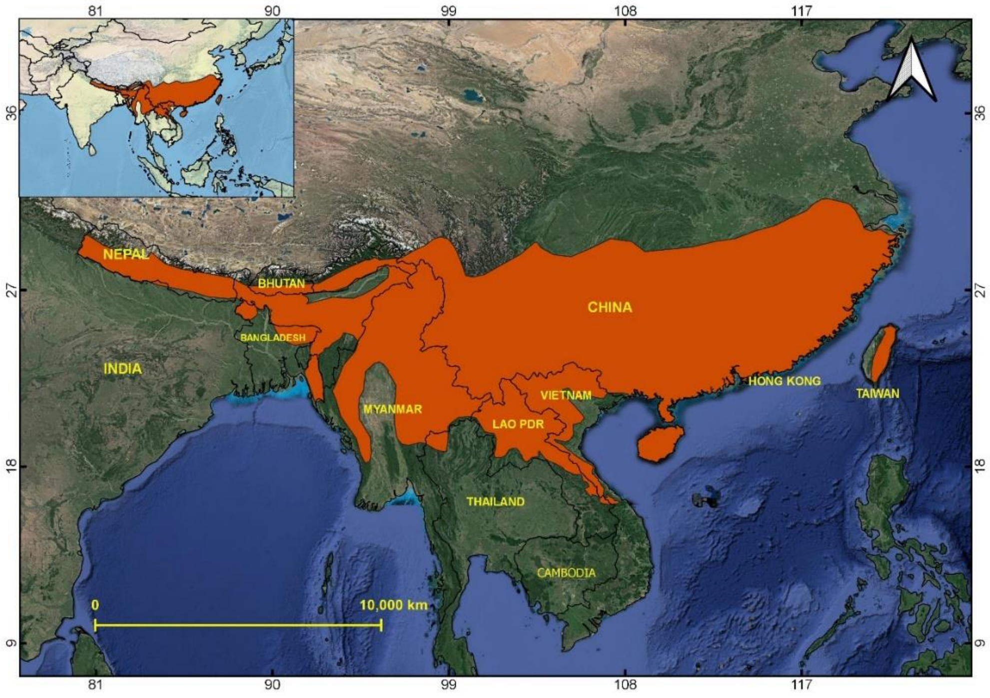


Figure 1: Global distribution of the Chinese Pangolin. Source: modified from IUCN 2022.

The Chinese Pangolin is widely distributed in the eastern, central, and western regions of Nepal, both within and outside the PAs. It has also been recorded in Far-western Nepal (Suwal et al. 2020). It is distributed within the range of 500–1,740 m elevation, with the occasional records from above 2,400 m elevation (Baral and Shah 2008, Jnawali et al. 2011, Sharma et al. 2020a). Outside the PAs, the Chinese Pangolin is recorded from Taplejung, Terathum, Illam, Panchthar, Jhapa, Sankhuwasabha, Dhankuta, Solukhumbhu, Khotang, Saptari, Sindhuli, Ramechhap, Dolkha, Sindhupalchowk, Kathmandu, Bhaktapur, Lalitpur, Kavre, Dhading, Makwanpur, Baglung, Gorkha, Lamjung, Palpa, Chitwan, Bardia, and Kanchanpur, while within the PAs it has been recorded from Shuklaphata, Bardia, Chitwan, Makalu Barun, Parsa, Sagarmartha and Shivapuri-Nagarjun National Parks, and the Annapurna, Gaurishankar, and Kanchenjunga Conservation Areas (DNPWC and DoF 2018, Suwal et al. 2020, Sharma et al. 2020a).

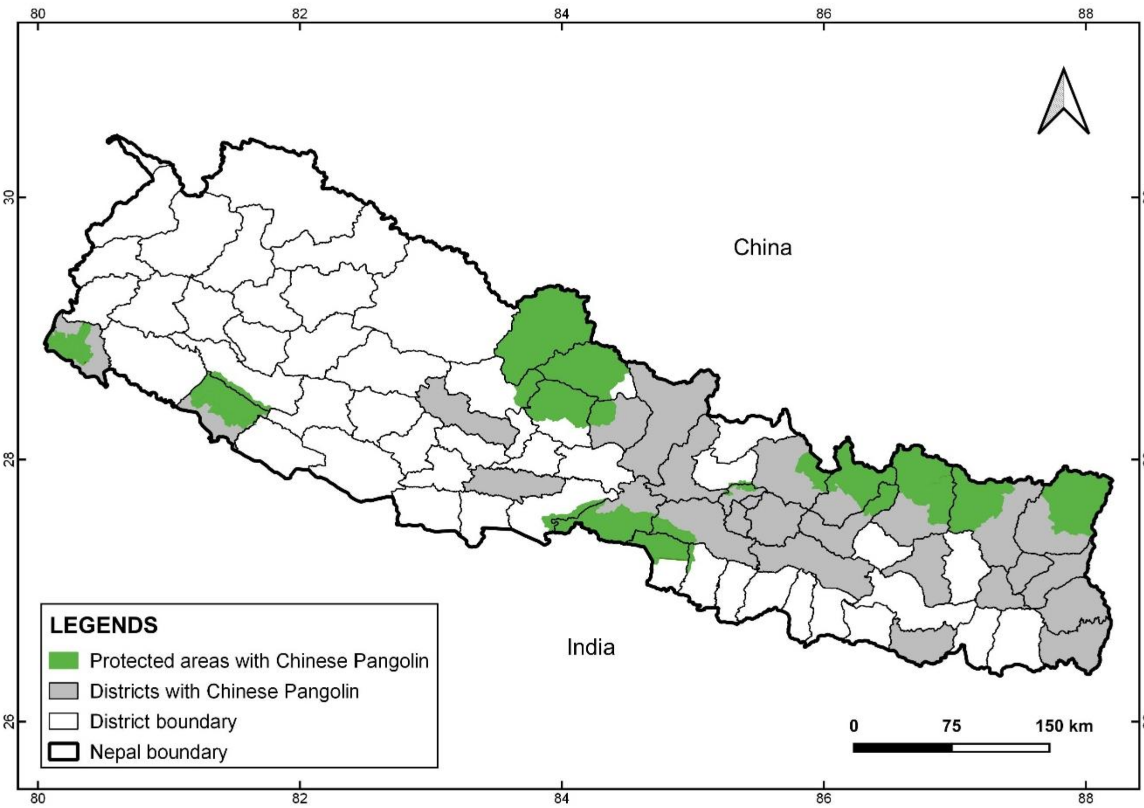


Figure 2: Distribution of the Chinese Pangolin in Nepal. Source: modified from DNPWC and DoF (2018).

2.5 Habitat and ecology

The Chinese Pangolin is found in a wide range of habitats including primary and secondary tropical, and subtropical rainforests (Chakraborty et al. 2002), limestone, bamboo, coniferous, mixed coniferous and broadleaf forests, grasslands, and agricultural landscapes, low mountain or hill forests (400–500 m elevations), and even some degraded habitats (Chao et al. 2005, Suwal et al. 2020, Wu et al. 2020, Sharma et al. 2020c). The pangolin seems to prefer broad-leaved forests because of the greater number of termites provided by such areas (Wu et al. 2004a). The pangolin populations were higher in primary forests, most likely due to the abundance of old hollow trees suitable for sleeping and serving as dens (Newton et al. 2008). The pangolins have also been observed in agricultural areas, such as cardamom and rubber plantation areas, and in forest patches adjacent to human-dominated landscapes (Thapa et al. 2014, Katuwal et al. 2017, Dorji et al. 2020, Suwal et al. 2020). The species inhabits in a wide range of elevations, from less than 100 m elevations in mid-hill forests in Taiwan (Wu et al. 2020) to 3000 m elevation in Nepal (Challender et al. 2019).

In China, the species can be found in mixed coniferous and broadleaf, evergreen broadleaf, and coniferous forests in the summer and shrub forests with a dense shrub layer that prevents air convection around burrow entrances in the winter (Wu et al. 2003). In southern Taiwan, the species was discovered to avoid major roadways despite being seen burrowing in the foundations of abandoned buildings (Wu et al. 2020). In Bangladesh, it has been found in primary and secondary evergreen forests, mixed evergreen and bamboo forests, and degraded teak habitats (Trageser et al. 2017). The Chinese Pangolin in Nepal occurs mainly in the dense broad-leaved forest dominated by *Schima wallichi, Myrica esculenta, Castanopsis* sp., and *Myrsine* sp. with dense shrub layers and is also recorded from agricultural lands and degraded habitats nearby human settlements (Katuwal et al. 2017, Suwal et al. 2020, Sharma et al. 2020b). Its occurrence is highly influenced by the altitude, aspect, slope, canopy, soil type, and vegetation type, the amount of food available, water, and degree of human interference (Sharma et al. 2020b).

The species appears to have distinct home ranges and, being fossorial, digs burrows for shelter and foraging on prey, and available research reveals having a polygynous social structure (Wu et al. 2020). The Chinese Pangolins use burrows to access prey, for shelter (including parturition), and to avoid predation (Bao et al. 2013). Burrows can be categorized into resident (or resting) and feeding burrows. Resident burrows are made up of an entrance with an unbranched tunnel that finishes into a chamber and can be used all year. Feeding burrows are much shorter than resident burrows and can be found in more open places, such as grassy hillsides (Wu et al. 2020). The Chinese Pangolins depend on burrows to maintain a consistent thermal environment all year round (Bao et al. 2013).

2.6 Behavior

The Chinese Pangolin is a solitary mammal and highly secretive (Wu et al. 2004a), making it difficult to study in the wild. It is nocturnal, emerging at night to forage after spending most of the day sleeping or resting in an underground burrow (Wu et al. 2005), being active between 19:00 and 22:00 at night (Fang and Wang 1980), foraging 5–6 km away from a resident burrow each night (Liu and Xu 1981). Because of its poor eyesight and hearing capacity, it locates prey depending upon the acute olfactory senses (Wu et al. 2005). Finding termitaria or ant nests is just one aspect of foraging; and other activities include digging through leaf litter and rotting wood. The powerful forelimb claws are used to dig into a nest or termitarium when they are found, with the hind limbs supporting the body. The tail is employed to give extra support when the substrate is difficult to excavate, allowing the forelimbs to exert more force and perform a better excavation. (Wu et al. 2005). After foraging, it will use its forelimbs or its head to dig a hole (5–10 cm deep) for urination and defecation and fill it with soil by dragging back and forth (Heath 1992).

The Chinese Pangolin is primarily terrestrial, however, is able to climb trees and swim well too, as other pangolin species (Wu et al. 2020). Pangolin scales provide a good defense against predators. When threatened by or detects a predator, it will either come to a complete stop and freeze, flee, or curl up into a ball. The species may roll down hillsides to evade predators and deter predators by hissing and puffing and lashing their sharp-edged tails, and the scales may be erected to withstand predators (Liu and Xu 1981, Zhang et al. 2016, Wu et al. 2020). The anal glands may also aid to repel predators by secreting a musky odor. Pangolins are dependent on their strong sense of smell to identify their territories by scent marking with urine and secretions from a scent gland located near their tails and by scattering feces (Wilson 1994, Wu et al. 2020).

2.7 Diet of the pangolins

Pangolins are characterized as eutherian mammals feeding on ants and termites with a unique external armor of overlapping scales (Swart 1992). Though pangolins are identified as ant and termite eaters, they are also found to feed on bees (pupas), flies, worms, crickets, insect larvae, earthworms, cockroaches, and beetles along with all life stages of prey including eggs, larvae, and imagoes, and castes (Fang and Wang 1980, Coulson 1989, Mahmood et al. 2013, Karawita et al. 2020). Pangolins are myrmecophagous and selective in their prey choice (Sweeney 1956, Swart 1996). They select specific ant and termite species rather than foraging on the most abundant species (Swart 1996, Pietersen et al. 2016a, Panaino et al. 2022). They also showed more preference towards ants than termites to feed on, as recorded in different dietary analyses. The Chinese Pangolin is also prey selective and it alone can feed on > 70 ant species (five families, twenty-five genera) and four termite species (two families, and four genera) (Sun et al. 2020b). The ant species included *Pheidologeton yanoi, Pheidole nodus, Polyrachis fervens, Crematogaster schimmeri, Camponotus monju,* and *Pseudolasius binghami,* and the termite species included mainly *Odontotermes formosanus*.

Lee et al. (2017) recorded a total of 25,803 ants and 812 termites, with six genera and nine species in the gut contents of a juvenile Chinese Pangolin representing ants as the main food source due to their species richness (eight species), abundance, and biomass. The presence of *Anoplolepis gracilipes*, which is an invasive ant species found in disturbed habitats, including near human settlements, in the analyzed diet suggests that this species forages at forest edges and in scrublands. Similarly, the Cape Pangolin feeds on 15 ant and one–five termite species (Coulson 1989, Swart et al. 1999, Pietersen et al. 2016a, Panaino et al. 2022). The ant species mainly included *A. custodiens*, *A. Steingroeveri*, Crematogaster sp., *C. thales*, *C. cinctellus*, and *P. schistacea* while the termite species included *Hodotermes mossambicus*, *Odontoternmes* sp., and *Trinervitermes trinervoides.* The Indian Pangolin was prey selective, feeding mainly on two black ant species, *C. confucii* and *C. compressus* and termite species, *O. obesus* (Mahmood et al. 2013, Irshad et al. 2015). The study of Ashokkumar et al. (2017) showed exclusive ingestion of *Leptogenys sp.* as this ant species was abundant. Red ant species like *Oecophylla* sp., *Carebara affinis*, and *Pheidole* sp. were also in the diet of the pangolin (Karawita et al. 2020, Katdare et al. 2021, Ram et al. 2022), showing a preference for greater variety but not abundant species as per the geographical variation.

The diet of the pangolins is temporal in nature. Variation in individual preferences and spatial and seasonal availability of prey may account for differences in prey species (Swart et al. 1999, Sun et al. 2020b). The pangolins are recorded to feed more on ant species during summer while termite species during winter as the prey availability varies with seasonal variation (Sun et al. 2020b, Panaino et al. 2022), where the ant species become more active towards the ground surface during summer and go into hibernation during winter, while the termite species become more abundant towards the ground surface during winter (Panaino et al. 2022). Pangolins ingested roughly twice as many insects during the wet season (June–October) as they did during the dry season (November–April). In contrast to the dry season, when the species may lose up to 25–30% of their body weight, species diversity and ant abundance were much higher in the wet season, leading to their body weight increment (Sun et al. 2020b). Shibao et al. (1999), also reported that the pangolins like eating foods high in protein, fat, and calories due to their strong digestive and absorption abililities in their small intestine.

The direct observation of the feeding behavior and bouts of the Temminck's Ground Pangolin showed a selective consumption of certain specific ant species over termite species rather than the abundant species. The most consumption of *A. custodiens,* a larger ant species (Coulson 1989, Richer et al. 1997, Swart et al. 1999), *A. steingroeveri (*Pietersen et al. 2016a, Panaino et al. 2022), and *Crematogaster* sp. (Sweeney 1956, Panaino et al. 2022) though presence of several ant species (>50 species) suggested selective feeding on specific species. The presence of medium to large sized ant species *C. brutus*, *Palthothyreus tarsatus*, and *P. militaris* and termite *Pseudacanthotermes militaris* in the Giant Pangolin's gut content and feces suggests that they consume relatively large preys in general and feed less on small species despite their greater abundance (Difouo et al. 2020). Larger prey species are preferred which may increase their foraging efficiency in terms of time, energy, and nutrient value.

Prey selectivity does not appear to be based on the size of the prey alone. Pangolins are attracted to arboreal surface prey (Swart 1996). Ants and termites present at the base, stems of trees and logs, under leaf litter, sandy flatter areas, plains, and bases of grass chumps seem to be preferred by pangolins (Wu et al. 2005, Pietersen et al. 2016a, Lee et al. 2017, Panaino et al. 2022), as they are easy to excavate being near the ground surface. The ecology of the most abundant prey species examined within the gut content (*C. nicobarensis*, *P. tyrannica*, and *Crematogaster dohrni*) of the Chinese Pangolin also suggests its preference for these arboreal or semi-arboreal species over ground-nesting species (Lee et al. 2017). Similarly, the termite species *Reticulitermes flaviceps* and *O. formosanus* are found on the soil surfaces, inside the wood, and in foraging tubes on the surface of tree trunks, dead grass, and fallen tree branches; they can be the prey for pangolins (Li et al. 2011). Ant and termite species with well-developed chemical and physical defenses are likely to be avoided (Redford 1985), and low density species might be more difficult to find or would require more effort to find, depending on how frequently they are encountered. As a result, pangolins may prefer medium to large sized, non-stinging and arboreal prey.

2.8 Threats

Poaching and Illegal trade

The Chinese Pangolin along with other Asian and African species is the most heavily trafficked wild mammal in the world, being at the risk of extinction (Challender et al. 2015). The major primary threat to pangolins is overexploitation by illegal hunting and poaching (Challender et al. 2019), both targeted and untargeted, for the illegal international wildlife trade and local use. According to recent estimates based on seizure data, more than 895,000 pangolins were trafficked globally between 2000 and 2019 (Challender et al. 2020). Pangolins have high economic value in the international market and are hunted for the purpose of obtaining profit (D'Cruze et al. 2018). However, it appears that local consumption is declining in favor of selling scales into illegal, international trade because of increasing demand and high prices in China as is the case in Bangladesh (Trageser et al. 2017), parts of China (Nash et al. 2016), northeastern India (D'Cruze et al. 2018) and Nepal (Katuwal et al. 2015, Sharma et al. 2020d). In the last decade, the rate and trend of trafficking of African pangolins to Asia have increased to meet the demand of Asia (Pietersen et al. 2014, Heinrich et al. 2016, Challender and Waterman 2017).

The pangolin is hunted because of the increasing demand for meat as a delicacy and for medicinal purposes (Challender et al. 2015, Katuwal et al. 2015, Mohapatra et al. 2015). Its various body parts such as blood, bones, claws, especially scales, and also the fetuses are used in traditional medicines for the treatment of different diseases and to increase healing power and for cultural purposes (Boakye et al. 2015, Katuwal et al. 2015, Mohapatra et al. 2015, Soewu and Sodeinde 2015, Nash et al. 2016) and pangolin meat is consumed by local people as a protein source and luxury food (Soewu and Ayodele 2009, Challender et al. 2019). Scales from pangolins are regarded as a lucky charm (D'Cruze et al. 2018) and are used to decorate lady bags, boots, jackets, and musical instruments as well as to make garlands and finger rings (Mohapatra et al. 2015, Soewu and Sodeinde 2015, Ghimire et al. 2020). Additionally, some locals believe that seeing a pangolin brings bad luck, and in such circumstances, infrequent killings are also documented (Thapa et al. 2014, Sharma et al. 2020c). In Pakistan, pangolins are killed due to negative beliefs such as, they eat human dead bodies by excavating the graves and harming the local people (Akrim et al. 2017). These beliefs have encouraged the selling or killing of the pangolins, resulting in the biggest threat to the pangolin population.

Habitat degradation and fragmentation

Habitat loss, degradation, and fragmentation are other major threats to pangolins as they are primarily found in intact forests (Wu et al. 2003, Katuwal et al. 2017, Sharma et al. 2020a). Wildlife and their habitat are both protected in PAs, restricting the human activities. However, the majority of the habitat of the Pangolin is outside of PAs (Sharma et al. 2020b) and is subjected to human activities such as deforestation, hunting, infrastructure development, residential expansion, logging, agricultural expansion, grazing, and other human activities that degrade biodiversity and result in the fragmentation, loss, or change of the original pangolin habitat. These activities either directly or indirectly affect pangolins by deteriorating their habitat, changing their diet, or both (Katuwal et al. 2017, Acharya et al. 2018, Sharma et al. 2020b), and also disturbing their migration between different habitats in search of suitable habitats (Zhang et al. 2021). Forest fire, electrocution on electric fences and pesticides use are all serious threats to the pangolin population (Pietersen et al. 2016b, Katuwal et al. 2017). Despite being skilled burrowers and climbers, research from Taiwan indicates that the Chinese Pangolins can get stuck in tree hollows or burrows which being a major cause of mortality (Sun et al. 2019).

2.9 Conservation status

The Chinese Pangolin is listed as a protected species in national or sub-national legislation in all the range states. The species can be found across its range in PAs, including the Chittagong Hill Tracts, Lawachara National Park, and nearby PAs in Bangladesh (Trageser et al. 2017); China: Dawuling Natural Reserve (Wu et al. 2003); India: Vamiki Tiger Reserve, Manas National Park, Sirohi Wildlife Sanctuary, Bunning Wildlife Sanctuary, and Yangoupokpi-Lokchao Wildlife Sanctuary, and Neora Valley National Park; Nepal: Kangchenjunga, Gaurishankar and Annapurna Conservation Areas, Makalubarun, Sagarmatha, Chitwan, Parsa, Shivapuri-Nagarjun, and Suklaphanta National Parks (DNPWC and DoF 2018).

The IUCN Red List of Threatened Species has listed the Chinese Pangolin as a Critically Endangered species because of its rapid decline due to poaching and illegal hunting (Challender et al. 2019). It is listed under Appendix I of the CITES as a heavily trafficked mammal (CITES 2022). It has been protected in Nepal under the National Parks and Wildlife Conservation (NPWC) Act 1973 (Jnawali et al. 2011). According to NPWC Act; section 26.2, the people who kills or injures a pangolin faces a fine of NPR 40,000 (USD 400) to NPR 75,000 (USD 750) and/or a prison sentence of one to ten years. Many community-based pangolin conservation initiatives are increasing in Nepal, where local communities are engaged and active in protecting the pangolins. The pangolin has been upgraded from a National Level II Protected Animal to Level I in China since 2020 for their better protection (Zhang et al. 2021). In Bangladesh, this species is protected by the Wildlife (Conservation and Security) Act 2012, while in India, this species is completely protected, being listed in Schedule I of the Wildlife Protection Act 1972 (Challender et al. 2019).

3. MATERIALS AND METHODS

3.1 Study area

The Chandragiri Municipality (27°43′36.49″N to 27°32′45.03″N and 85°16′39.51″E to 85°11′8.68″E) is situated to the South-west part of Kathmandu District in Bagmati Province of Nepal (Figure 3), and covers an area 43.9 km^2. It has predominantly hilly terrain. Settlements and farming seem to develop along the less sloppy region. The highest altitude of the municipality is 2551 m and lowest altitude is 1310 m.

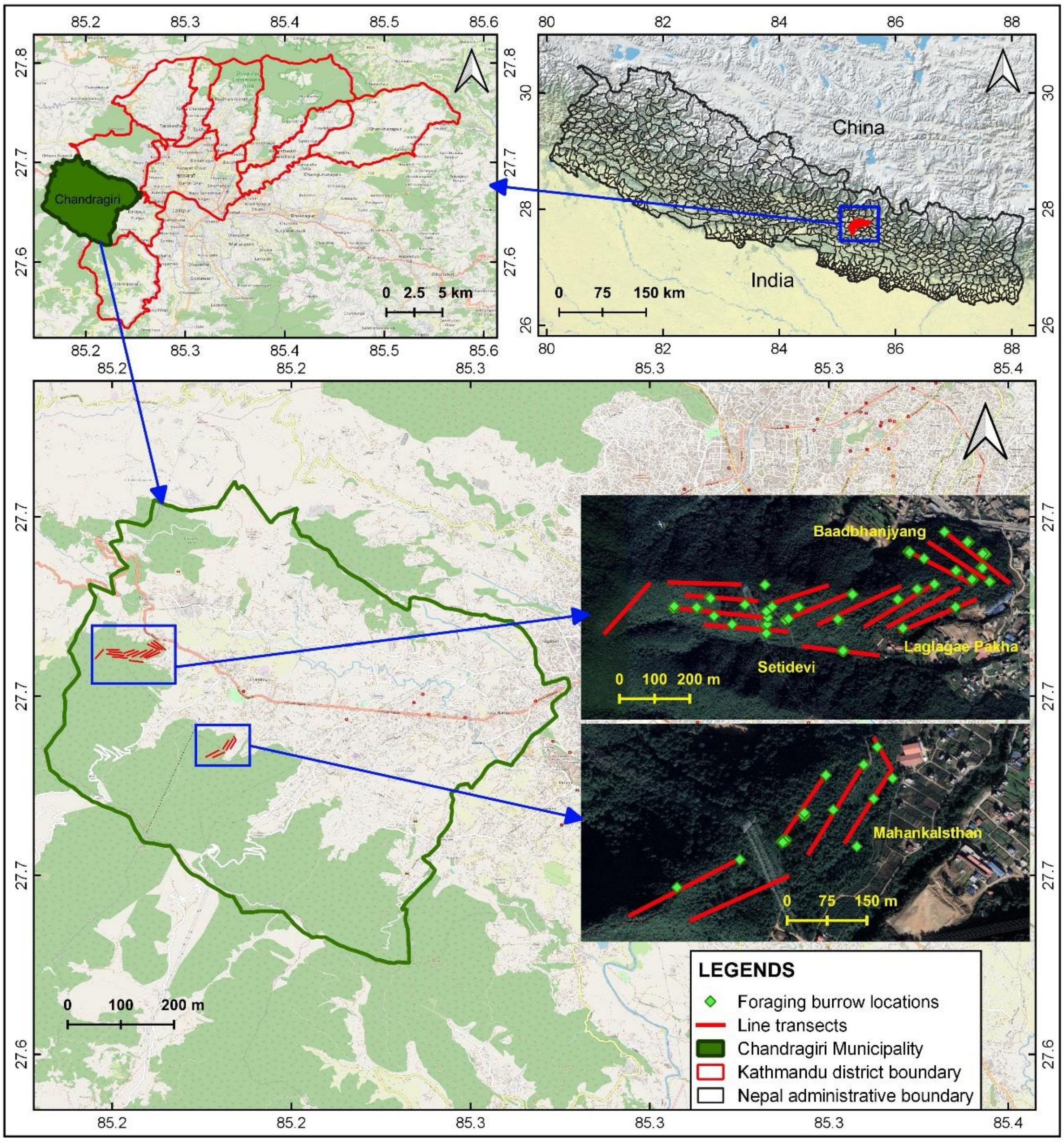


Figure 3: Chinese Pangolin study area with established line transects and foraging habitat locations in Chandragiri Municipality.

The city's main attraction includes Chandragiri Hill, with its Cable Car and is rich with high biodiversity value. The human population of the study area is 136,928 with the density of 3,118/km^2 with main ethnic groups Newar, Brahman, Chhetri, Tamang, and Magar (CBS 2021).

3.1.1 Climate

Chandragiri Municipality lies in subtropical climate zone (1,000–2,000 m) and Deciduous Monsoon Forest Zone (altitude range of 1,200–2,100 m). The highest temperature in Chandragiri is recorded to be maximum during the month of May and June and the lowest temperature is recorded in December and January.

3.2.2 Floral and faunal diversity

Vegetation of the study area is of mixed type consisting mainly Nepalese Alder (*Alnus nepalensis*), Needlewood (*Schima wallichii*), Indian Chestnut (*Castonopsis indica*), Chinkapin (*Castanopsis tribuloides*), Pine (*Pinus roxburghii*), *Quercus* spp., *Rhododendron arboreum*, Nepali Hog Plum (*Choeospondias axillaris*), Blueberry Myrtle (*Myrsine semisirretta*), Kafal or Box Berry (*Myrica esculenta*), Champa (*Michelia champaca*), Himalayan Ash (*Fraxinus floribunda*), Marking Nut (*Semicarpus anacardium*), Oval-leaf Lyona (*Lyonia ovalifolia*), etc. A total 69 taxa belonging to 35 families of vascular plants have been recorded along the trail of Chandragiri Hills. The hill contains both natural and reforested forest. The area has 30 mammal species, 199 bird species, 34 herpetofauna, and 77 butterfly species (Katuwal et al. 2020). Some of the important mammal species in this region are Large Indian Civet (*Viverra zibetha*), Masked Palm Civet (*Paguma larvata*), Yellow-throated Marten (*Martes flavigula*), Jungle Cat (*Felis chaus*), Golden Jackal (*Canis aureus*), Chinese Pangolin (*M. pentadactyla*), Hoary-bellied Squirrel (*Callosciurus pygerythrus*), Leopard Cat (*Prionailurus bengalensis*), Leopard (*Panthera pardus*), and Wild Boar (*Sus scrofa*) (Katuwal et al. 2020).

3.2 Materials

- GPS: Garmin Etrex 10: Location points and elevation
- Measuring tape: Distance measurement
- DBH tape: Diameter of tree specimens
- SILVA Type15 Clinometer: Slope and aspect
- Spherical Densiometer (Model C): Forest canopy coverage

- Ziploc bags and Silica gels: Fecal samples
- Vials and Forceps: Ant and termite specimens
- Alcohol (70%): Preservation of ant and termite specimens, laboratory analysis
- BestScope, BS-3020T Stereo microscope: Laboratory analysis

3.3 Research design

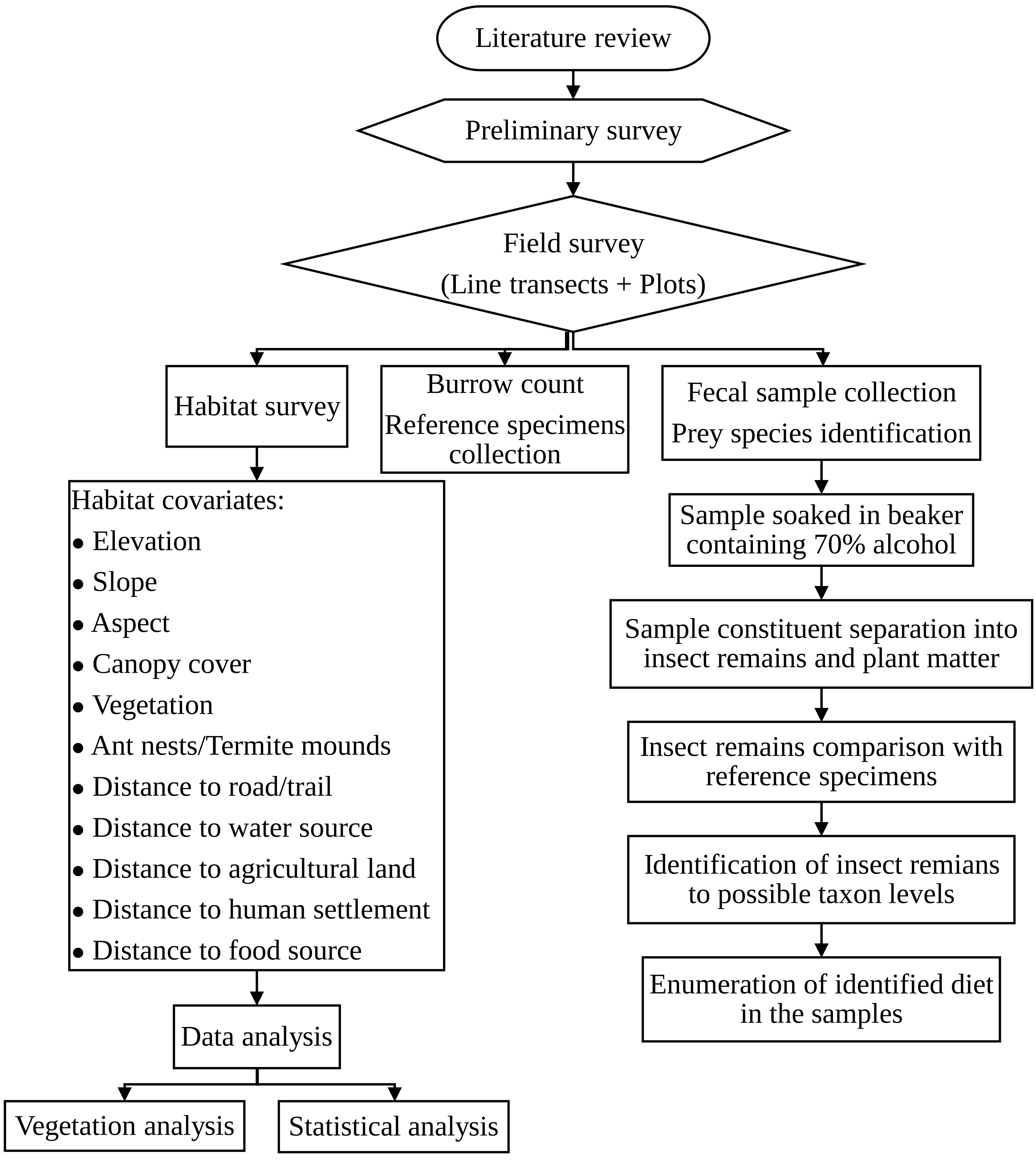


Figure 4: Diagrammatic representation of the research design

3.4 Data collection

3.4.1 Habitat covariate data collection

A preliminary survey was carried out from 25 February to 5 March 2021. During that time, the physiographic condition of the study area and potential distribution sites of the Chinese Pangolin were identified after field visits. Four community forests of Chandragiri Municipality namely Mahankal, Setidevi, Laglagae Pakha, and Baadbhanjyang Community Forests were selected for the research based on the accessibility (slopes > 45° were excluded) and distribution of the burrows of the pangolin. The burrows were classified into three main types on the basis of observation as fresh/new, old, and foraging burrows (Photograph 1). The burrows that had compact and dry soil with dry fodders and spider web along with seedlings of vegetation were considered as old burrows and the burrows that had fresh, loose soil with fresh scratches, and pugmarks without dry fodders in the burrow, and any seedling of vegetation were taken as fresh burrows (Katuwal et al. 2017). The burrows that were visually less deeper than fresh burrow with small opening hole and presence of ant, and termites were known as foraging burrows (Dorji et al. 2020).

Photograph 1: Different burrow types of the Chinese Pangolin in Chandragiri Municipality, Nepal.

The field survey was conducted in the study area from November 2021 to March 2022. A total of 20 line transects (average length: 300 ± 5.48 m SD) were laid. The first transect was started from random point and the remaining transects were laid systematically at the distance interval of 50 m from each transect. Five plots of size 10 m × 10 m per transect were established at the interval of 50 m distance. In each plot, the burrow occurrence, presence of fecal samples, and 12 habitat covariates such as availability of food (presence/absence of ant nests or termite mounds), presence/absence of fallen logs, elevation, slope, aspect, canopy coverage, vegetation, and distance to the nearest water sources, roads/trails, human settlements, agricultural lands, and food sources were recorded. The presence/absence of ant nests and termite mounds were also noted based on the presence of ant nests and termite mounds in and nearby the plots. The distance of ant's nest and termite mounds were measured from the center of each plot using a measuring tape. Aspect and slope were recorded using SILVA Type15 Clinometer, while the coordinates and elevation were recorded by using a handheld GPS Garmin Etrex 10 from the center of each plot. The number, Diameter at Breast Height (DBH) and height of each tree were recorded in each plot. The DBH of a tree was measured at the standard height of 1.3 m using a DBH tape. Vegetation with girth size > 5 cm and height of >1.5 m were considered trees and below these values were included in the saplings. The forest canopy coverage was measured using Spherical Densiometer (Model C) from four corners and one from the center of the plot. The distance between the plot and the nearest road/trail, water source, human settlement, and agricultural land were measured using a measuring tape within 25 m and more than this distance range was obtained using Google Earth Pro.

3.5 Fecal sample collection and laboratory analysis

The Chinese Pangolin's fecal samples were collected from the burrow openings of the species to identify the diet composition. The fecal sample of the Chinese Pangolin was identified by visual observation and the presence of chitin parts in the feces (Chame 2003, DNPWC 2019). Each fecal sample was collected and preserved in a dry state using silica gels in a Ziploc bag for laboratory analysis.

Photograph 2: Scat samples of the Chinese Pangolin.

Ant and termite specimens (and other possible insects) were also collected in a vial containing 70% ethanol for reference from different feeding sources potentially preyed upon by the Chinese Pangolins. The reference specimens were collected by hand-picking method from their nests and foraging burrows.

In the laboratory, the taxonomic keys available for ants (Nazarreta et al. 2019, AntWeb 2022, AntWiki 2022), termites (Kalleshwaraswamy et al. 2013), and other invertebrate (Halstead 1986, BugGuide.Net 2022) were used for the identification of insect residuals and these are identified up to order, family, genus or species levels where possible. Each fecal sample was soaked in a beaker containing 70% ethanol and separated manually using a glass rod and dissecting needles. The separated matter was transferred to Petri dishes, and insect matter was separated using a stereo microscope (BestScope, BS-3020T). The separated insect constituents were compared with reference samples of ants and termites collected from different sites in the study area. While doing so the reference ants and termites were broken into pieces with a pestle, and the broken parts were compared with the residuals found in the fecal samples.

3.6 Data analysis

3.6.1 Vegetation analysis

The Importance Value Index (IVI), for tree species was calculated by using formulae (Curtis 1959):

$$\text{Relative Density (\%)} = \frac{\text{Number of individuals of species}}{\text{Total number of individuals of all species}} \times 100$$

$$\text{Relative Frequency (\%)} = \frac{\text{Number of quadrates in which a species occur}}{\text{Total number of all species in the quadrates}} \times 100$$

$$\text{Relative dominance (\%)} = \frac{\text{Total basal area of a species}}{\text{Total basal area of all species}} \times 100$$

$\text{Basal area} = \frac{\pi D2}{4}$, D = Diameter at Breast Height

$$\text{Importance Value Index (IVI)} = \text{Relative Frequency} + \text{Relative Density} + \text{Relative Dominance}$$

3.6.2 Statistical analysis

The distribution pattern of the pangolin was analyzed by calculating the ratio of variance to mean (S^2 / a) (Krebs 1999). The ratio (S^2/a) is commonly known as the index of dispersion and it gives the scattering of individuals in a population through space. The sample variance (S^2) gives us a good measure of the evenness of species distribution.

$$S^2 = \frac{\sum_{i=1}^{n}(X - a)^2}{n - 1}$$

Where, X = sample value i.e. number of burrows

a = mean value

n = total sample number

If (S^2 / a) = 1, Distribution is random

(S^2 / a) < 1, Distribution is uniform or regular

(S^2 / a) > 1, Distribution is clumped

Generalized Linear Model of binomial family (Logistic regression) was used to determine the association between the Chinese Pangolin presence-absence and habitat covariates as elevation (m), slope (°), canopy coverage (%), distance to water source (m), road (m), settlement (m), agricultural land (m), and ant nests (m), number of ant nests, and tree abundance in the study area. Prior to this analysis, the variables were tested for correlation to prevent the multi-collinearity in the models (Figure 5). Distance to agricultural lands was strongly correlated with elevation (r = 0.955) and distance to settlements (r = 0.991) hence only distance to agricultural lands was included in the model while acknowledging in interpretation that this variable also reflects elevation and distance to settlements because the agricultural lands are the potential food sources of the Chinese Pangolin. The model averaging was conducted to estimate 95% confidence intervals for each variable, established at statistical significance at $\alpha < 0.05$ (Burnham and Anderson 2002). All statistical tests were performed in R program (R Core Team 2019). The study map layout was created by the help of QGIS 3.12 Bucuresti.

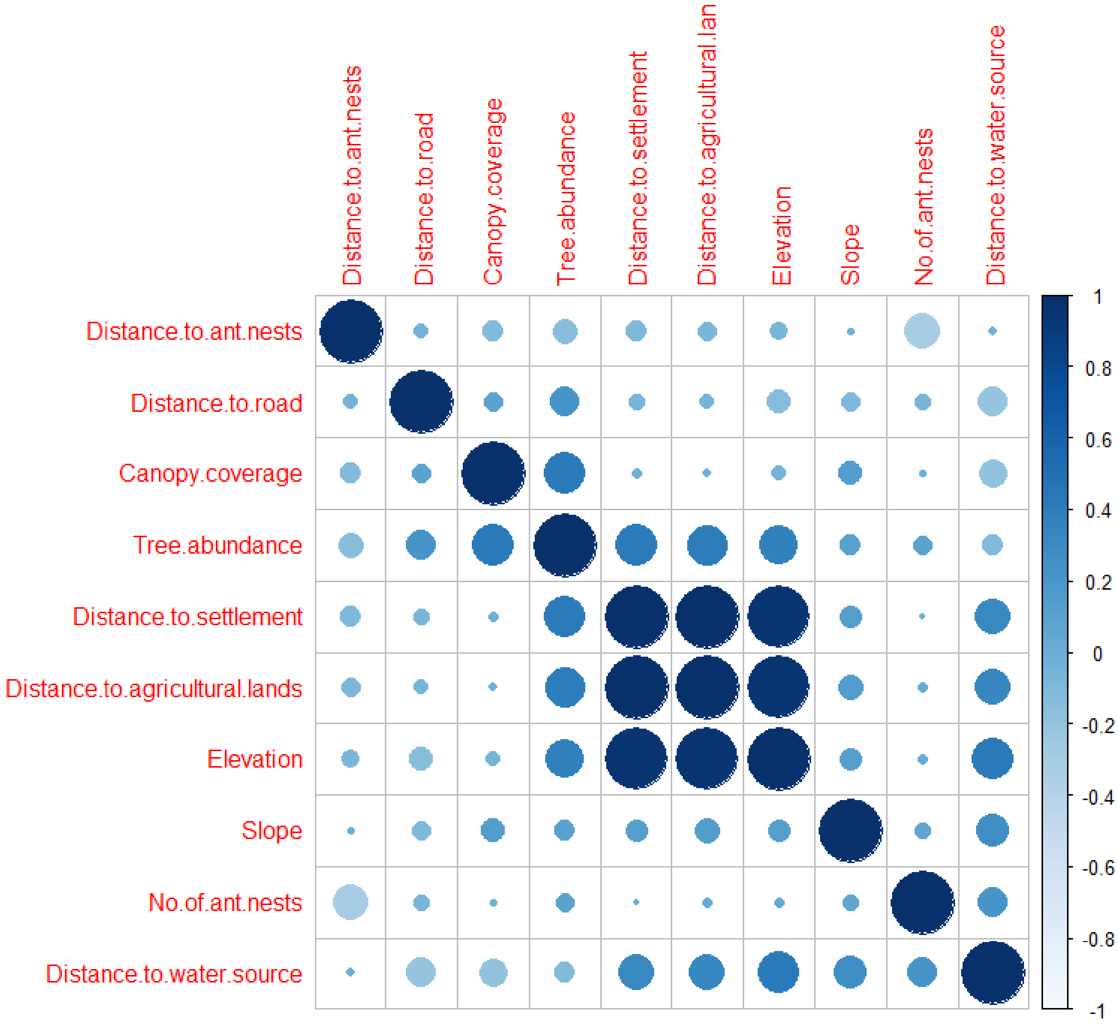


Figure 5: Correlation matrix between predictive variables to estimate factors influencing the Chinese Pangolin occurrence in Chandragiri Municipality.

4. RESULTS

4.1 Diet of the Chinese Pangolin

A total of 15 ant species belonging to five families; Dolichoderinae, Dorylinae, Formicinae, Myrmicinae, and Ponerinae, and one termite species belonging to family Kalotermitidae were collected as the reference specimens (Table 1). Three beetle species of the families Scarabaidae, Coccinellidae, and Latridiidae were also collected from the foraging burrows of the Chinese Pangolin.

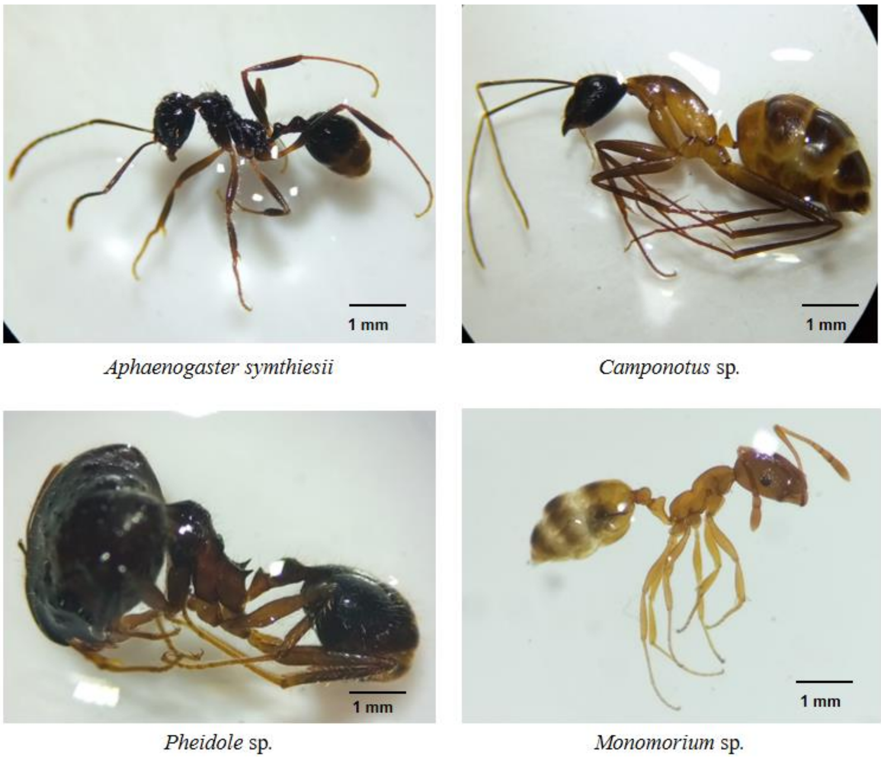
Table 1: Reference ant and termite specimens of Chandragiri Municipality

Sub-Family	Ant species	Family	Termite species
Dolichoderinae	*Dolichoderus* sp.	Kalotermitidae	*Cryptotermes* sp.
Dorylinae	*Aenictus binghami*		
Formicinae	*Camponotus* sp.	**Family**	**Beetle species**
	Nylanderia sp.	Scarabaidae	Scarab/Dung beetle
	Prenolepis sp.	Coccinellidae	Ladybug
Myrmicinae	*Aphaenogaster symthiesii*	Latridiidae	Scavenger beetle
	Crematogaster sp. 1		
	Crematogaster sp. 2		
	Crematogaster sp.3		
	Polyrhachis lacteipennis		
	Lophomyrmex sp.		
	Monomorium sp.		
	Pheidole sp.		
Ponerinae	*Brachyponera chinensis*		
	Ectomomyrmex sp.		

A total of 10 fecal samples of the Chinese Pangolin were collected and their fecal analysis revealed the body parts of ants, insects, plant matters, and soil debris. The soil and plant debris were recorded in a greater proportion, followed by the body parts of ants. Other insect remains of beetles, mites, crickets, and bugs were also recorded from the fecal samples in minor amounts but no remains of termites were found from any of the samples. A total of one ant species and three genera of ants were recorded as prey items in the fecal samples of the Chinese Pangolins from the analysis including *Aphaenogaster symthiesii*, *Camponotus* sp., *Pheidole* sp., and *Monomorium* sp. (Table 2). Along with these ant species, the body remains of other insects such as bug, beetles, soil mites, and mole crickets were also found (Table 2).

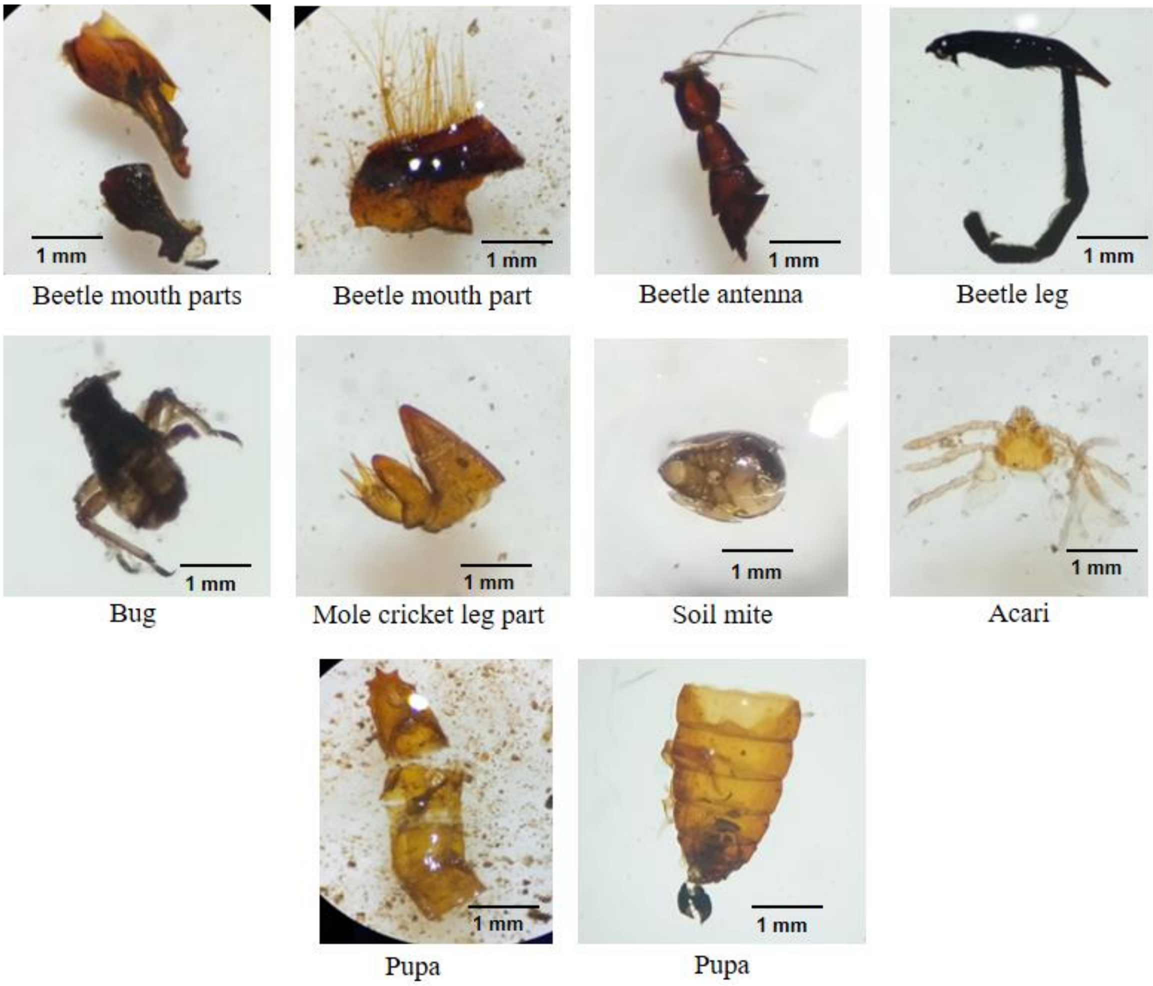
Table 2: Ant and insect body remains in the fecal samples of the Chinese Pangolin.

Insects	Body remains found
Aphaenogaster symthiesii	Mandibles, thoraces, legs
Camponotus sp.	Mandibles
Monomorium sp.	Whole body part with thorax and legs
Pheidole sp.	Mandibles
Bug	Whole body
Beetles	Leg, mouth parts, antenna
Soil mite	Whole body part
Pupae of unidentified insect	Covering of pupa
Mole cricket	Leg parts



Photograph 3: Major ant species in the diet of the Chinese Pangolin.

Photograph 4: Body parts of the ants observed in fecal samples of the Chinese Pangolin.



Photograph 5: Body parts of the other insects observed in fecal samples of the Chinese Pangolin.

4.2 Distribution of burrows of the Chinese Pangolin

A total of 100 survey plots were established in the study area within the forests from where a total of 99 burrows were recorded in 40 surveyed plots. The burrows included 11 living fresh burrows, and 88 foraging burrows with the maximum burrows (n = 31, 31.3%) recorded from the Mahankal community forest (Table 3). The average number of burrows per plot was 0.99, the variance was 4.78, and the ratio of variance to mean was 4.83 which is greater than 1. The index showed the clumped distribution of the burrows at the four sites of the Chandragiri Municipality.

Table 3: Burrow type and distribution in Chandragiri Municipality in 2021.

Community forests	Burrows	
	Resident	Foraging
Mahankal	1	30
Setidevi	2	15
Laglagae Pakha	4	19
Baadbhanjyang	4	24
Total	**11**	**88**

4.3 Foraging habitat of the Chinese Pangolin

The burrows of the Chinese Pangolin were found between the elevation range of 1,500 to 1,800 m above sea level [(average 1585 ± 72.99 m (SD)], and no observation beyond 1,800 m of elevation (Figure 6). Majority of the burrows (46.5%, n = 46) were recorded in the slope range of 30–40° and the least (13.1%, n = 13) within the slope range 10–20° (Figure 7). A total of 28.3% (n = 28) burrows were recorded on the South and Southeast facing slopes, followed by East (18.2% n = 18). The least number of burrows were recorded from North facing slope with 11.1% (n = 11) occurrence of the burrows. The Northwest, Southwest and West face did not encounter any burrows (Figure 8). Most of the burrows were recorded in dense forest having canopy coverage between 50–75% (n = 62) under the dominant tree species including *Schima wallichii*, *Castanopsis tribuloides*, *Pinus roxburghii*, *Myrica esculenta*, and *Myrsine* sp. (Figure 9)

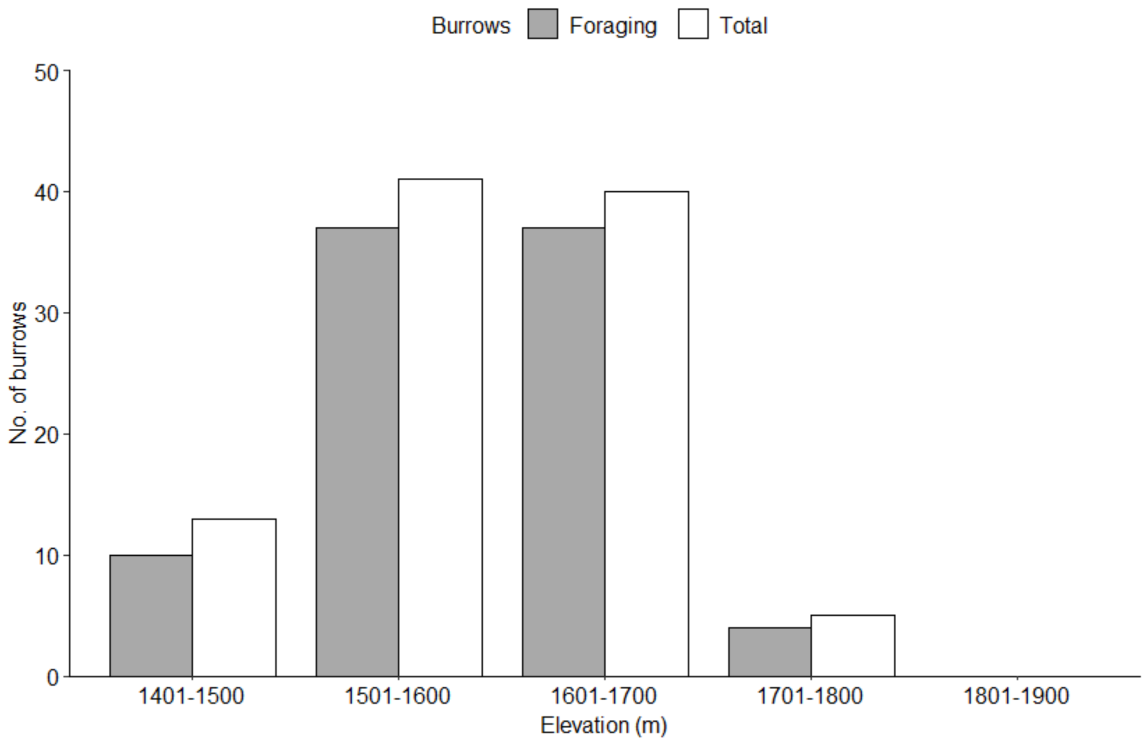


Figure 6: Distribution of the Chinese Pangolin burrows with elevation in Chandragiri Municipality in 2021.

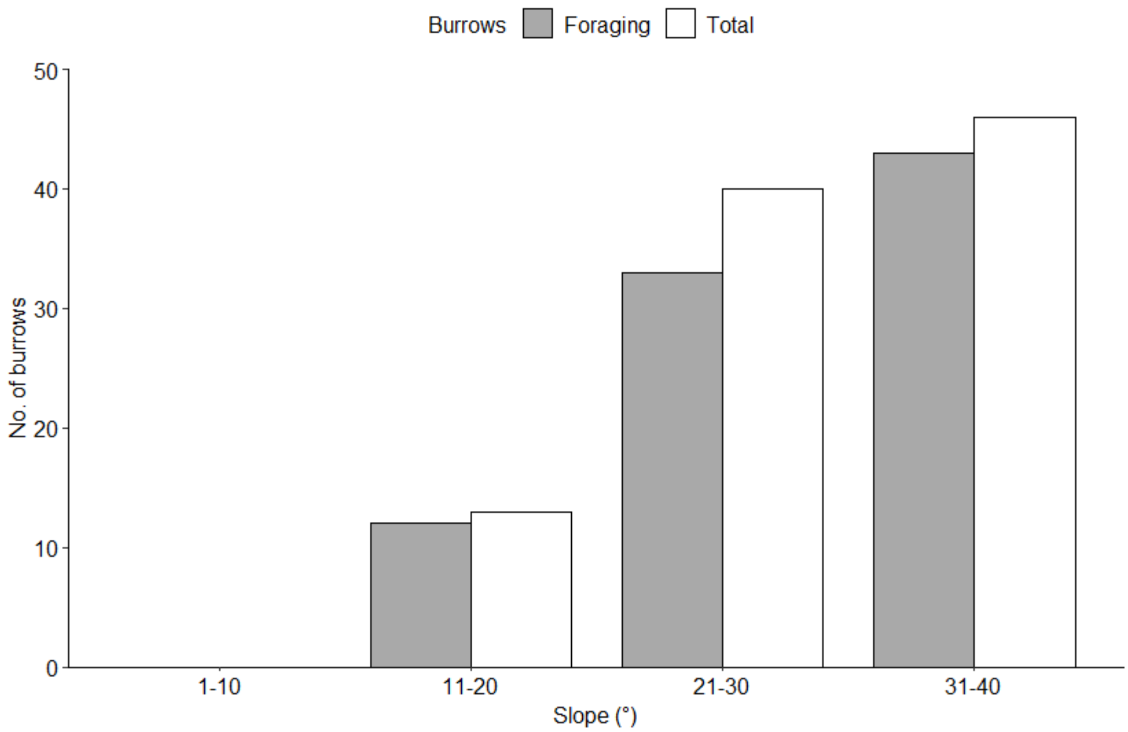


Figure 7: Distribution of the Chinese Pangolin burrows with slope in Chandragiri Municipality in 2021.

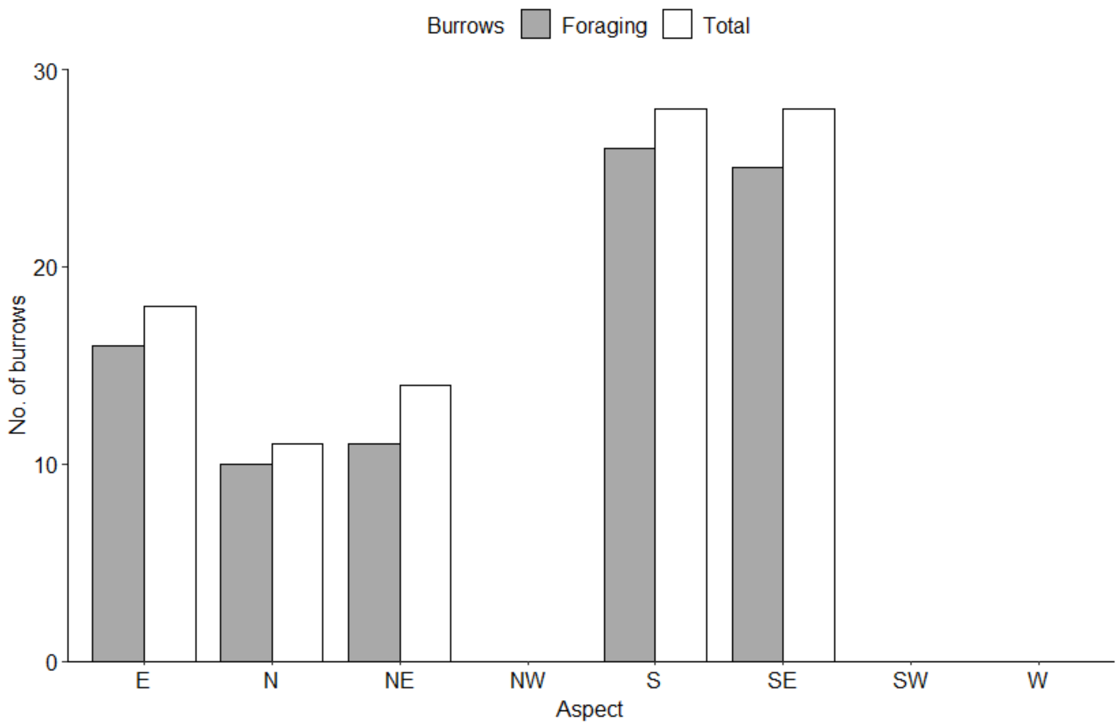


Figure 8: Distribution of the Chinese Pangolin burrows with aspect in Chandragiri Municipality in 2021.

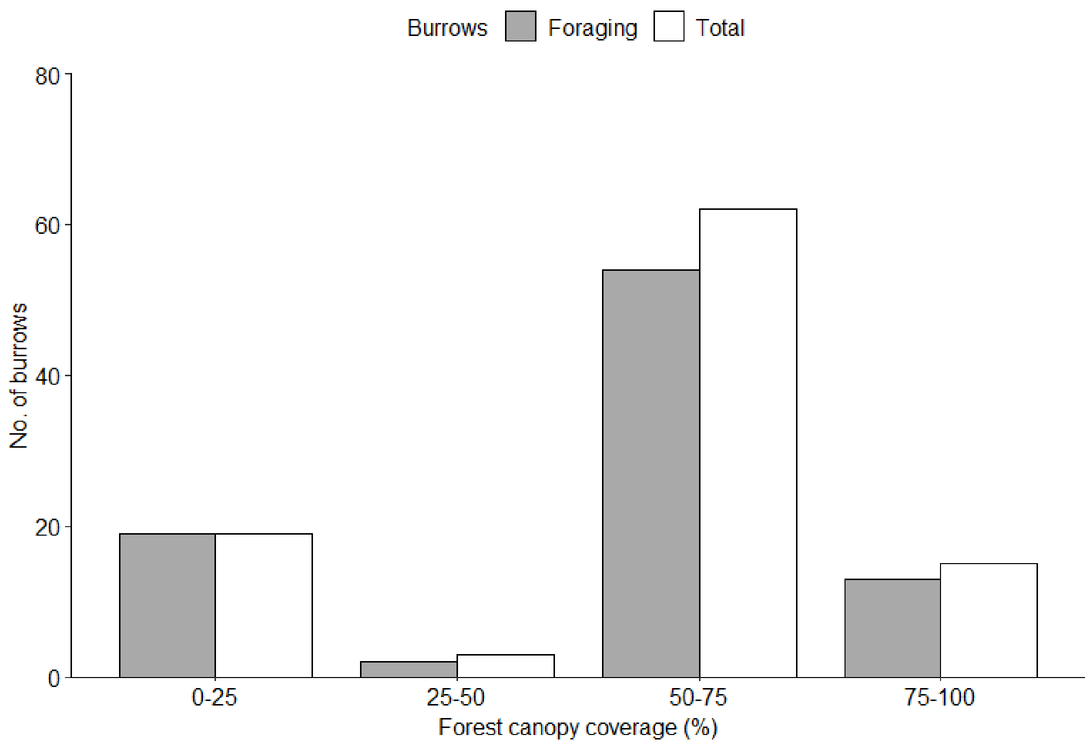


Figure 9: Distribution of the Chinese Pangolin burrows with forest canopy coverage in Chandragiri Municipality in 2021.

The average distance of the nearest road from the center of the plots was 28.2 ± 52.3 m (range: 1 to 272.3 m), and the majority of burrows (88%, n = 88) were within the distance of 100 m from the nearest road (Figure 10). Remaining 12% (n = 12) burrows were recorded far from 100 m distance from the nearest road. The average distance of the nearest water source was 81.9 ± 114.2 m (range: 1.8–536.5 m) from the center of the plots in the study area. The higher number of burrows (55.6%, n = 55) were recorded within 100 m from the water source followed by 43.4% (n = 43) burrows recorded within 300 m from the water source (Figure 11). No burrows were recorded beyond 400 m from water source. The average distance of human settlement from the study plots was 254.9 ± 238.6 m (range: 47.3–939.8 m), and nearly half of the burrows (46.5%, n = 46) were recorded within 200 m from the nearest human settlement areas (Figure 12). 50.5% (n = 50) of the burrows were recorded between 200–600 m distance, and only 4% (n = 4) were recorded at 600 – 800 m from the settlement. Similarly, the average distance of agricultural land from the center of study plots was 276.5 ± 253.1 m (range: 58–1025 m), and 78.8% (n = 78) of the burrows were recorded within 1– 400 m distance (Figure 13). The average ant nest distance from the study plots was 6.8 ± 11.3 m (range: 0.5–30 m), and the highest frequency (72.7%, n = 72) of the Chinese Pangolin burrows were recorded near the ant nests (Figure 14).

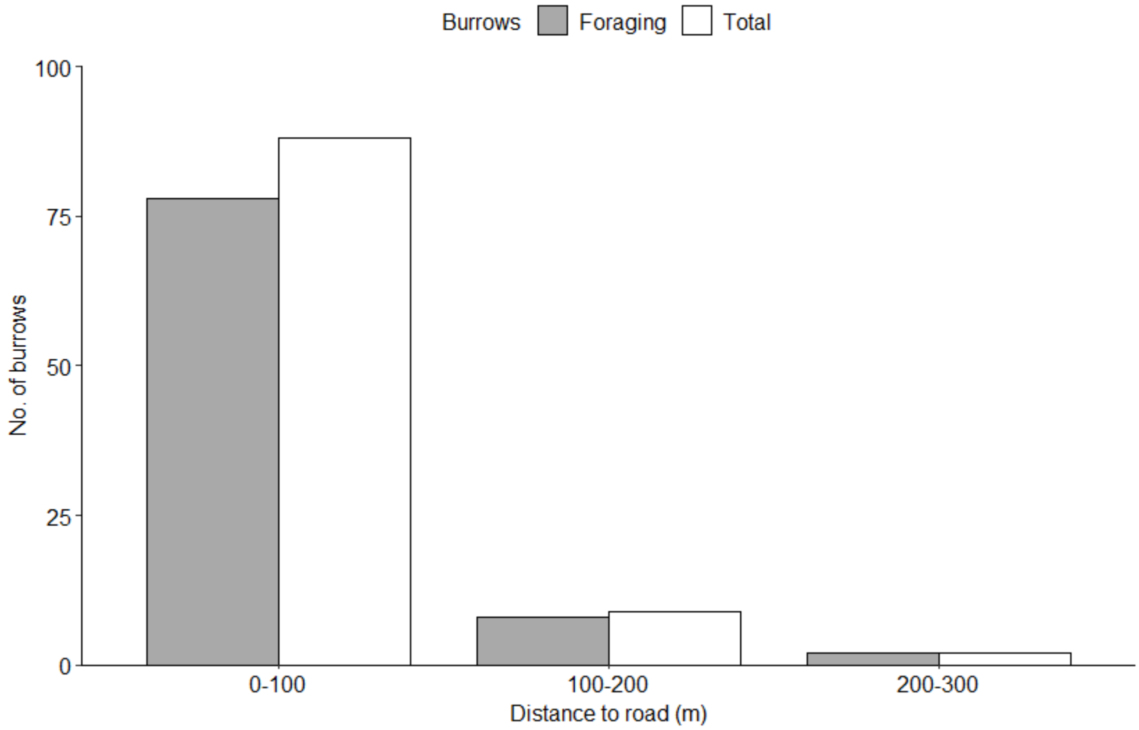


Figure 10: Distribution of the Chinese Pangolin burrows with distance to the nearest road in Chandragiri Municipality in 2021.

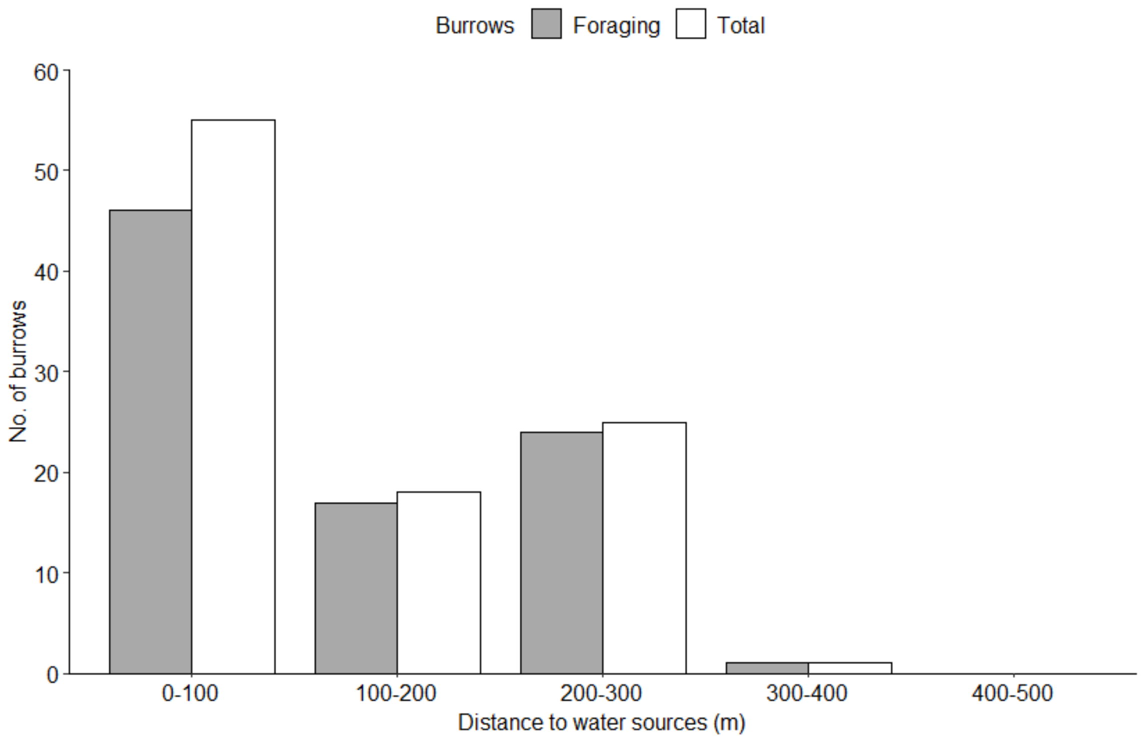


Figure 11: Distribution of the Chinese Pangolin burrows with distance to the nearest water source in Chandragiri Municipality in 2021.

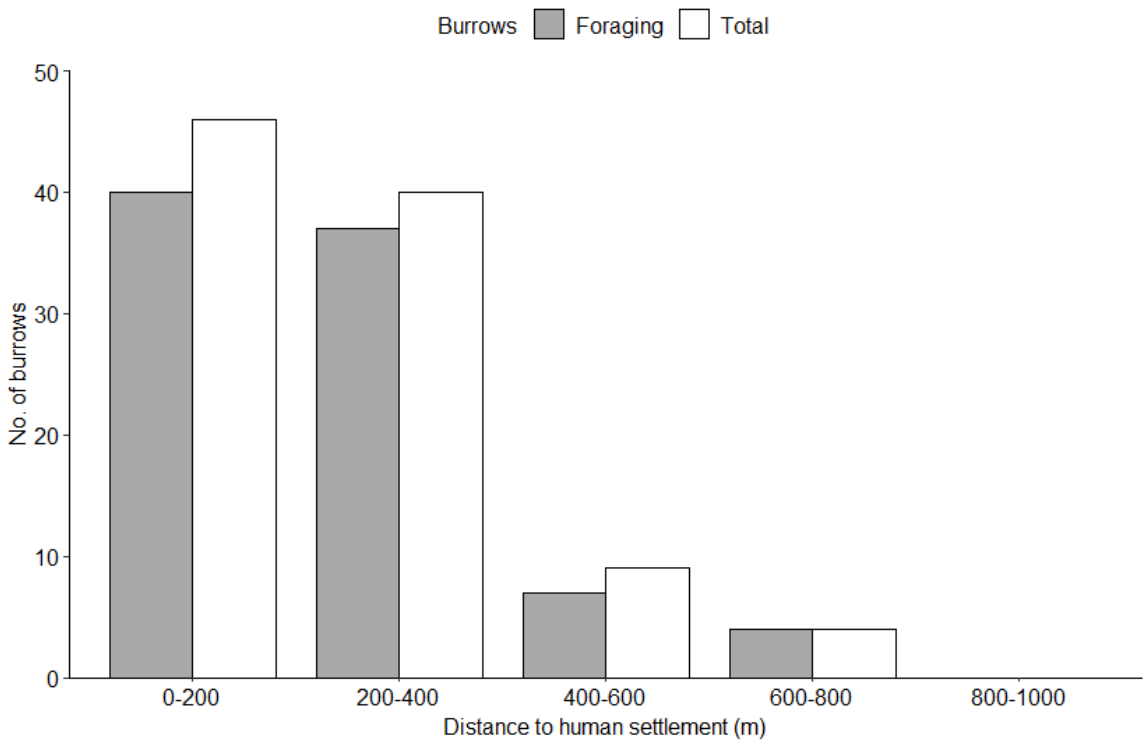


Figure 12: Distribution of the Chinese Pangolin burrows with distance to human settlements in Chandragiri Municipality in 2021.

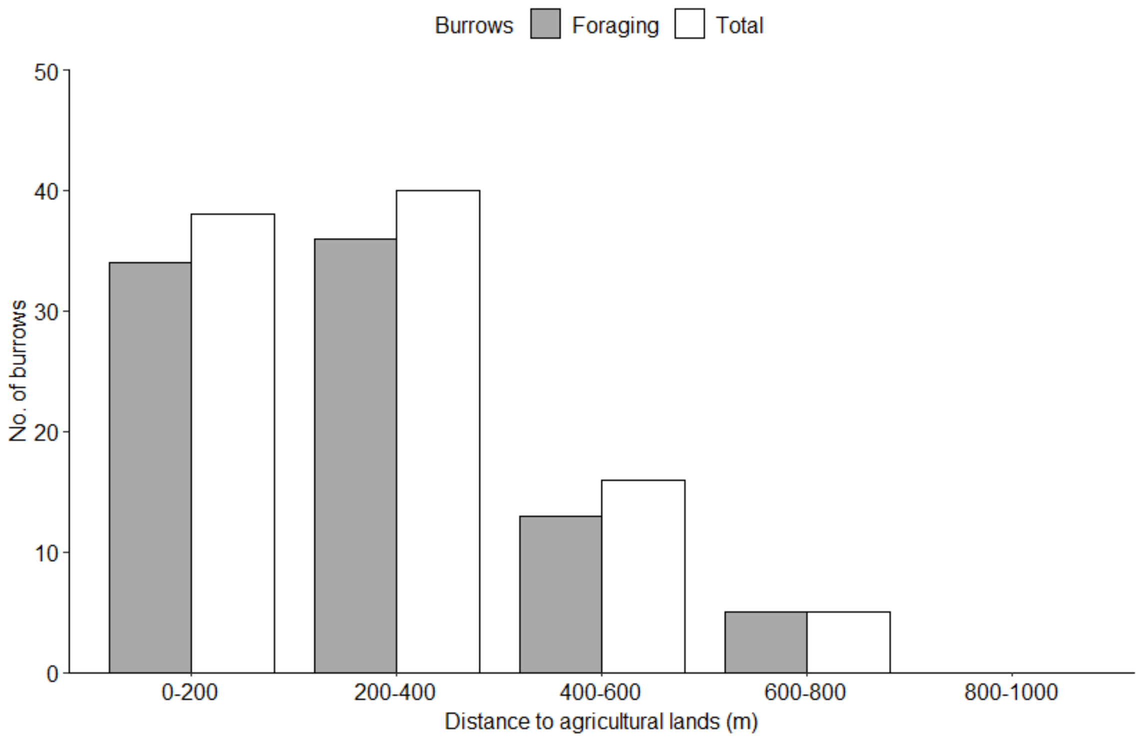


Figure 13: Distribution of the Chinese Pangolin burrows with distance to agricultural lands in Chandragiri Municipality in 2021.

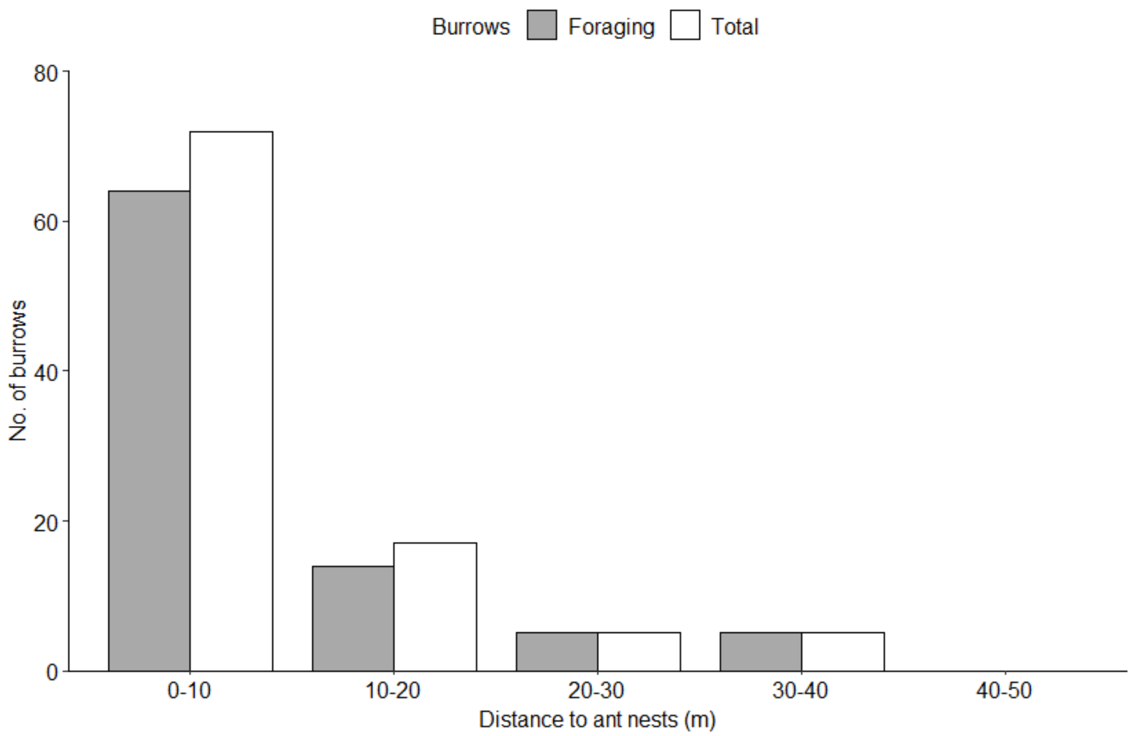


Figure 14: Distribution of the Chinese Pangolin burrows with distance to the nearest ant nests in Chandragiri Municipality in 2021.

A total of 1267 tree vegetation belonging to 36 species of 22 families and six unidentified tree species were recorded form the study plots. The burrows of the Chinese Pangolins were found in the mixed vegetation habitats dominant with *Schima wallichii* having higher IVI = 51.55 followed by *Castanopsis tribuloides* (IVI = 42.40), *Pinus roxburghii* (IVI = 26.18), and *Myrica esculanta* (IVI = 24.08) (Table 4).

Table 4: Importance Value Index (IVI) of tree species in Chandragiri Municipality in 2021.

S.N.	Name of tree species	Relative frequency	Relative density	Relative dominance	IVI
1	*Acer* sp.	0.22	0.16	0.67	1.05
2	*Albizia* sp.	1.33	0.47	5.95	7.76
3	*Alnus nepalensis*	0.22	0.16	3.22	3.60
4	*Berberis asiatica*	0.22	0.08	0.77	1.07
5	*Camelia kissi*	0.44	0.16	0.49	1.09
6	*Castanopsis hystrix*	0.88	0.55	1.56	2.99
7	*Castanopsis indica*	0.66	0.24	2.99	3.89
8	*Castanopsis tribuloides*	13.56	26.83	2.02	42.41
9	*Celtis* sp.	0.44	0.71	2.18	3.34
10	*Choerospondias axillaris*	1.11	0.39	2.15	3.65
11	*Cleyera japonica*	0.22	0.08	1.71	2.01
12	*Cleyera* sp.	8.44	6.47	0.75	15.66
13	*Cornus* sp.	0.22	0.08	0.67	0.97
14	*Eurya acuminata*	7.11	4.42	1.24	12.78
15	*Eurya cerasifolia*	0.22	0.08	0.67	0.97
16	*Fraxinus floribunda*	0.22	0.08	1.64	1.94
17	*Ficus* sp.	2.00	1.10	3.58	6.69
18	*Leucaena leucocephala*	0.44	0.16	2.33	2.95

19	*Lyonia ovalifolia*	1.56	0.87	0.84	3.27
20	*Machilus odoratissima*	0.22	0.16	6.61	6.99
21	*Madhuca longifolia*	0.67	0.31	2.73	3.71
22	*Myrica esculenta*	13.56	8.84	1.69	24.09
23	*Myrsine capitellata*	1.33	0.87	1.08	3.28
24	*Myrsine semiserrata*	0.44	0.16	0.93	1.53
25	*Pinus roxburghii*	9.78	6.47	9.99	26.25
26	*P. wallichiana*	0.44	0.24	16.66	17.34
27	*Pyrus communis*	0.22	0.08	2.52	2.82
28	*Quercus glauca*	1.56	1.26	1.24	4.06
29	*Quercus semecarpifolia*	0.67	1.10	2.08	3.86
30	*Rhododendron arboreum*	5.11	4.26	0.71	10.08
31	*Rhus succedanea*	1.56	0.79	0.73	3.07
32	*Rhus wallichi*	0.67	0.24	0.80	1.71
33	*Schima wallichii*	19.56	29.36	2.66	51.57
34	*Swida oblonga*	0.44	0.39	1.64	2.48
35	*Symplocos lucida*	0.22	0.24	1.37	1.83
36	*Syzygium cumini*	2.00	1.03	1.56	4.58
37	Species A	0.22	0.08	1.87	2.17
38	Species B	0.22	0.31	0.11	0.65
39	Species C	0.22	0.08	1.32	1.62
40	Species D	0.22	0.08	0.47	0.78
41	Species E	0.44	0.24	2.62	3.20
42	Species F	0.67	0.31	3.10	4.09

4.4 Factors affecting the distribution of burrows

Table 5: Model-averaged parameter estimates and 95% confidence limits, describing the occurrence of the Chinese Pangolin (*Manis pentadactyla*) in Chandragiri Municipality in 2021. Model parameters include slope (°), canopy coverage (%), elevation (m), distance to road (m), water sources (m), agricultural lands (m), and ant nests (m), ant nests number, and tree abundance. Estimates are averaged from all models with significant effects in bold.

Variables	Estimate	SE	Lower Limit	Upper Limit	Z	P
Intercept	-0.127	1.473	-3.056	2.932	0.085	0.932
Slope	0.077	0.035	0.008	0.145	2.190	**0.029**
Canopy coverage	-0.031	0.021	-0.071	0.012	1.459	0.144
Distance to road	0.006	0.005	-0.003	0.015	1.405	0.160
Distance to water sources	-0.001	0.003	-0.006	0.005	0.213	0.831
Distance to agricultural lands	-0.003	0.001	-0.006	-0.001	2.619	**0.009**
Number of ant nests	0.122	0.237	-0.341	0.622	0.509	0.611
Distance to ant nests	-0.060	0.024	-0.107	-0.013	2.514	**0.012**
Tree abundance	0.079	0.051	-0.024	0.179	1.513	0.130

The Chinese Pangolin burrow occurrence was greatly influenced by slope, distance to agricultural lands and distance to ant nests. The occurrence of burrows was increased with increasing the slope, and the burrow occurrence was decreased with increasing distance to agriculture lands and increasing distance to ant nests (Table 5). The Chinese Pangolin burrow occurrence was decreased with increasing forest canopy coverage and increasing distance to water sources without major variation (Table 5). Whereas the Chinese Pangolin burrow occurrence was increased with increasing the number of ant nests, tree abundance and increasing the road distance (Table 5).

5. DISCUSSION

5.1 Diet of the Chinese Pangolin

The Chinese Pangolin is a myrmecophagous mammal feeding exclusively on ants and termites with occasional foraging on other insects such as beetles, bugs, crickets, and mites. The presence of only four ant species as *A. symthiesii*, *Camponotus* sp., *Monomorium* sp., and *Pheidole* sp. in the fecal samples among 15 ant species collected from the study area as references that can be the potential prey species, convey that the pangolin is prey selective feeding only on specific ant species. It also suggests that the pangolin preys on the most available specific species rather than the most abundant prey species. The primary ant prey species *A. symthiesii*, *Camponotus* sp., and *Pheidole* sp. in the fecal samples of the Chinese Pangolin showed that it feeds on the larger ant species (> 5 mm) over small ones. The selection of larger ants might be to increase their foraging efficiency, as larger species provide more energy and nutrient intake efficiently in short feeding duration compared to the smaller sized prey (Swart et al. 1999). Also, prey selection is determined by the depth and easy availability of the prey species (Lee et al. 2017, Panaino et al. 2022). These ant species recovered as the pangolin diet are nested not too deep under the soil, stones, and rotten logs/branches which can be foraged with ease in less energy and time expenditure in raiding their nests but higher food intake, which is more efficient for the juvenile pangolins (Lee et al. 2017) as compared to the prey species that nests deeper under the soil.

The selection of certain prey species for over abundant potential prey species might also be due to the chemical and mechanical defense mechanism of the prey species. The pangolins avoid ant and termite species with well-developed defense systems (Redford 1985). Subfamily Ponerinae has a sting for their defense against the predators as in Myrmicinae but is the most painful (Lee et al. 2017), which might be the reason for the avoidance of ant species such as *Brachyponera* and *Ectomomyrmex* by the pangolin even they were present in the samples collected for as the reference specimens. Though termites are also the prey source of the Chinese Pangolin were not found in the fecal samples. The reason might be their complete digestion after being ingested by the pangolins, as termites are soft-bodied compared to ants (Katdare et al. 2021). Pangolins prefer ants over termites (Swart et al. 1999, Pietersen et al. 2016a, Sun et al. 2020b, Panaino et al. 2022) either due to their well-developed defense mechanism or their low abundance of diverse species. The termite species are also not easily available to prey on as they can build their mounds deeper (> 1

m) from the surface or with strong outer structure of compact soil that makes the pangolins inaccessible of termites; as though have morphological adaptations to digging they are not well adapted for digging deep as other myrmecophagous mammals as the aadvarks, Giant Anteaters, and the Giant Pangolins (Swart et al. 1999).

The diet of the Chinese Pangolins was not only the ants but also other insects, soil debris, and plant matters. The soil and plant matters are not actually the diets of the pangolins, instead, these are taken up unintentionally during the process of foraging on the prey species as the tongue of the pangolin is copiously lubricated for insect adheretion. The presence of more soil debris and plant matters in the diet of the pangolin might be due to lower activities of the prey species and scarcity in food sources (Anderson 2004), as the study was conducted during the winter season. In winter, the prey species dig deeper from the soil surface leading to lower prey abundance and lower prey accessibility to the pangolins (Panaino et al. 2022). This can cause the intake of more soil and plant matters while foraging on the scarce prey species and feeding on other available insects as beetles, crickets, and insect pupae other than ants and termites to compensate the prey scarcity. However, the plant matters might be an important source of fibre and protection for the stomach walls of the pangolins from gastric juice during less insect digestion (Pietersen et al. 2016a).

5.2 Foraging habitat of the Chinese Pangolin

The study of the burrow occurrence of the Chinese Pangolin within the forest areas of four community forests recorded the clumped distribution of the burrows along with the variation in elevation, slope and aspect of the study area. This clumped distribution of the pangolins might be the areas where they occurred had the suitable habitats with sufficient sunlight and food sources as needed for their survival. The occurrence of the burrows within the medium range of 1,500 to 1,700 m elevation might be due to the availability of the diverse prey species, which tend to decrease with increasing elevation (Hemachandra et al. 2014). The presence of burrows at the slope range 30° – 40° showed the preference for neither low nor highly steep slopes for habitat selection. The pangolin seems to prefer steeper slopes (30° – 60°) to maintain the stable temperature inside the burrows and availability of the termites (Wu et al. 2003), and the avoidance of the slopes more than 60° is possibly due to less food availability or inconvenience for their activities (Heath 1992). The steeper slope also helps pangolins to get the mud out of their burrows, saving energy for burrowing, and avoiding rainstorms that would wash the burrow opening (Wu et al. 2003). Similarly, the preference for a slope less than 25° by the pangolin might be for the easy movement than the terrain slope (Acharya et al. 2021). Aspects also play the important role in the distribution of burrows. The highest frequency of burrows in Southeast and South is probably due to warmer habitat than other aspects. The preference towards East and South aspects and strong avoidance towards North aspect might be for direct light penetration to the burrows and it helps for maintaining the temperature during the winter season (Wu et al. 2004a).

The distribution of the burrows in closed forests of 50 – 75% coverage with dominant vegetation as *S. wallichi, C. tribuloides, P. roxburghii,* and *M. esculenta* can imply that the pangolins prefer areas with dense coverage over too sparse or too dense regions as reported by Suwal et al. (2020). The Chinese Pangolins have a poor defense against predators (Nowak 1999), so a dense canopy coverage helps them avoid predators by providing a hideout (Maurice et al. 2019). Also, the pangolins have poor capacity to adapt to changing temperatures, hence, they need habitats with dense cover for insulation to exchange heat between the environment and burrows (Wu et al. 2003). Similarly, the ants and termites, the primary prey of the pangolins, are more abundant and diverse in the dense forest canopies (Axelsson and Andersson 2012, Corro et al. 2019), which provides better food sources. The closed-canopy forests protect the forest moisture (Maurice et al. 2019) and soil from excessive erosion (Katuwal et al. 2017), providing steady habitat for the pangolins. The areas with dense canopy have less undergrowth vegetation which helps for the easy movement of the pangolins and may encourage them to make living burrows in those habitats (Karawita et al. 2018).

The factors like the distance to the water source, road, settlement, and agricultural lands also have influence in burrow distribution of the Chinese Pangolins. The higher burrow occurrence within 100 m from the nearest water source might be due to the frequent need for water for pangolins, and also the preference of ants, termites, and other insects to moist habitats (Cornelius and Osbrink 2010, Shrestha et al. 2021). Their presence near the water source might preserve their energy taken to travel between the water source and living/foraging burrows and avoid predators while travelling such long distance for drinking. Similarly, more burrows were recorded near the road (within 100 m) and fewer away from the undisturbed areas. However, the distance had no significant effect on the distribution of the burrows. This occurrence of the pangolins near the roads might be due to the presence of some prey species that thrive in disturbed habitats (Lee et al. 2017) but also increase their risk of human encroachment as illegal hunting and poaching (Katuwal et al. 2017), and their habitat destruction due to trampling by the humans as an excuse of trekking/hiking.

Most of the burrows in the study area were near the agricultural lands and human settlements as community forests are generally located near these areas and had the significantly affected burrow occurrence. Agricultural lands are rich in ants and termites as the habitats necessary for these prey species as leaf litters, and animal dungs (Richer et al. 1997) are present in the lands and hence can be considered as potential habitat for the Chinese Pangolin (Sharma et al. 2020a). The areas near the settlements are mostly disturbed, that might provide suitable habitats for some ants and termites to thrive increasing food sources. However, anthropogenic activities such as frequent collection of fuel wood and fodder, livestock grazing in the forests near to the settlements, and use of the pesticides and insecticides in the agricultural land close to forests can cause disturbance and decrease in prey availability that can harm the occurrence and survival of the pangolins (Sharma et al. 2020b).

The decrease in the number of burrows with the increase in distance from the nearest food source; ant nests might be supported by the fact that pangolins are specialist species feeding only on ants and termites, and for the pangolins to thrive, there should be a natural abundance of its prey species in their habitat (Wu et al. 2004a, Maurice et al. 2019). The burrows are also dug near the food source for the easy availability of prey and less energy expenditure on food searching (Heath and Vanderlip 1988). The high prey species abundance and richness favor pangolin occurrence (Swart et al. 1999). The observation showed more significant burrows in areas with lower tree abundance but dominated by *S. wallichii, C. tribuloides, P. roxburghii*, and *M. esculenta*. These tree species are usually found in well-drained soil (Orwa et al. 2009), and the preference of well-drained soil by the pangolin for burrowing might represent the association in the occurrence of the species within the habitat dominant by these tree species. These tree species also have higher crown density and hence provide denser canopy coverage. This higher coverage provide a greater amount of leaf litters that can contribute to the soil moisture protection and provision of greater quantity and diversity of food and nesting resources for ants and termites (Corro et al. 2019, Pratiknyo et al. 2020) which are the common prey of the pangolins.

6. CONSLUSION AND RECOMMENDATIONS

6.1 Conclusion

The burrows of the Chinese Pangolins were clumped in distribution, recorded only from the four community forests of the Chandragiri Municipality. The Chinese Pangolin is prey selective feeding on only four ant species amongst the 15 prey species. The diet included the ant species and other insects as prey items and no remains or traces of the termites in the fecal analysis showed that the pangolin favors ants over termites. The selection of the foraging habitats by the pangolin was based on the habitat factors such as slope, distance to agricultural lands, and distance to ant nests. The pangolins seem to prefer habitats in the vicinity to the agricultural lands, and areas with abundant ant nests within steep slopes.

6.2 Recommendations

Based on the observations and results of the entire study following recommendations are emphasized:

- Because of the low number of fecal samples of the Chinese Pangolin, the recorded diet could not be quantified, hence the further research on the diet is important to get the more detailed information on the diet of the Chinese Pangolin.
- More researches are needed to identify the potential impacts of agricultural lands on the Chinese Pangolin occurrence.
- The forests habitats with dense canopy cover should be maintained.

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PHOTO PLATES

Reference specimens


Aenictus binghami


Brachyponera chinensis


Crematogaster sp 1


Crematogaster sp 2


Crematogaster sp 3


Dolichoderus sp.


Ectomomyrmex sp.


Lophomyrmex sp.

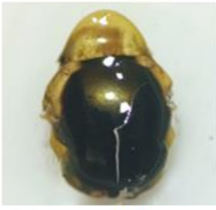

Nylanderia sp.


Prenolepis sp.


Polyrachis lacteipennis


Cryptotermes sp.


Latridiidae beetle


Scarabaedae beetle

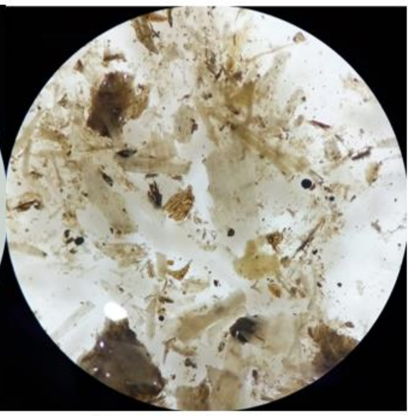

Coccinellidae beetle

Fecal samples and Laboratory analysis


Scat samples of the Chinese Pangolin


Scat sample observation under stereo microscope


Insect remains in scat sample


Plant matters in scat sample

Field Gallery

Ant nest

Ant nest

Termites

Burrow in red soil

Burrow in brown soil

Burrow in yellowish soil

Survey areas

animals

MDPI

Article

Foraging Burrow Site Selection and Diet of Chinese Pangolins, Chandragiri Municipality, Nepal

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Simple Summary: As one of only eight species of pangolin, the Chinese pangolin (*Manis pentadactyla*) of Nepal inhabits forests, agricultural lands, and grasslands. Its population is declining due to hunting and habitat loss, and it is listed as critically endangered. Accurate information on its habitat and diet can aid in the development of site-specific management plans. Habitat characteristics such as forest canopy cover, slopes, and distance to agricultural lands and the nearest ant nests are important factors influencing the occurrence of the Chinese pangolin. Fecal analysis revealed that the ant species *Aphaenogaster symthiesii*, *Camponotus* sp., *Monomorium* sp., and *Pheidole* sp. were the dominant prey in the Chinese pangolin's diet. This study provides baseline information to aid Chinese pangolin conservation in Nepal.

Abstract: The Chinese pangolin (*Manis pentadactyla*) is a myrmecophagous, nocturnal mammal species that occurs in forests, agricultural lands, and grasslands. It is critically endangered due to illegal hunting and habitat loss. Characterizing the Chinese pangolin's habitat and diet could improve our knowledge of the conditions necessary for species persistence; however, limited information is available. We investigated the habitat and diet of Chinese pangolins in the Chandragiri Municipality, Kathmandu, Nepal from November 2021–March 2022. We identified foraging burrows within plots established along 20 transects, collected scats opportunistically at these burrows, and used a generalized linear model to assess the site-level habitat characteristics related to burrow occurrence. We recorded 88 foraging burrows which occurred in forests with 50–75% canopy closure at 1500–1700 m elevation with 20–40° slopes. The probability of detecting a Chinese pangolin foraging burrow was greater with the increasing slope gradient and decreased with increasing distance to agricultural lands and ant nests or termite mounds. The analysis of 10 scats revealed that *Aphaenogaster symthiesii*, *Camponotus* sp., *Monomorium* sp., and *Pheidole* sp. were the dominant ant prey species; no termites were detected. Baseline data from this study could be used for ex-situ conservation and the captive breeding of Chinese pangolins as well as aiding site-specific management plans in Nepal.

Keywords: Chinese pangolin; prey species; foraging habitat; myrmecophagy

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1. Introduction

The foraging site selection and the diet of species provide insights into their ecology and habitat use [1]. The knowledge of foraging ecology and diet is essential for developing conservation action and management plans for species' long-term persistence [2,3] and their impacts on the prey species [4]. This knowledge is particularly important for species that are endangered or are of conservation concern.

The Chinese pangolin (*Manis pentadactyla*, Linnaeus 1758) is one of the four Asian pangolin species and occurs in Nepal, India, China, Taiwan, Bangladesh, Bhutan, Myanmar, Lao PDR, Thailand, and Vietnam [5]. The Chinese pangolin occurs in primary and secondary tropical forests [6], grasslands, agricultural areas, and some degraded habitats [7–11]. Chinese pangolins tend to inhabit broad-leaved forests because of the greater abundance of termites [12]. However, their occurrence can also be influenced by elevation, slope gradient, canopy cover, and the distance to water and human activity [9,13–15]. Chinese pangolins are nocturnal and have adapted for digging burrows which are used for hunting prey, shelter, and avoiding predators [12,16].

The Chinese pangolin is considered vulnerable to human threats due to its low reproductive rate, poor self-defensive mechanisms, and narrow habitat requirements [12]. It is classified as Critically Endangered by the International Union for Conservation of Nature (IUCN) Red List of Threatened Species [5]. The Chinese pangolin is listed under Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora [17] and protected in Nepal under the National Parks and Wildlife Conservation (NPWC) Act 1973 [18]. Human threats to the Chinese pangolin include illegal hunting for its flesh and scales [5] as well as habitat alteration and degradation [7,11,19]. Pangolins are among the few myrmecophagous mammal species [20], with specialized anatomical and morphological adaptations for foraging primarily on termites and ants [21–24]. They opt for specific ant and termite species rather than foraging on the most abundant species [23,25,26]. The Chinese pangolin selects ants over termites as prey, feeding on over 70 species of ant and 4 termite species [27]. Dominant ant prey species include *Pheidologeton yanoi*, *Pheidole nodus*, *Polyrachis fervens*, *Crematogaster schimmeri*, *Camponotus monju*, and *Pseudolasius binghami*, and the dominant termite prey species is *Odontotermes formosanus*. Chinese pangolins also appear to help control the invasive ant *Anoplolepis gracilipes* [28]. Therefore, the conservation of the Chinese pangolin could help maintain ecosystems by regulating insect populations [5,19] and provide ecosystem services by improving soil quality and mitigating the crop damage caused by termites and ants [8,29].

Because of their nocturnality, adaptations for burrowing [30,31], and their tendency to forage 5–6 km from their resident burrows each night [32], the foraging behavior and ecology of pangolins are difficult to observe in the field. Their specialist diet also makes them difficult to maintain in captivity for observational studies [33]. Consequently, there is limited knowledge regarding the foraging ecology and diet of the Chinese pangolin. We characterized the foraging burrow site selection of the Chinese pangolin and identified prey remains from scats associated with these burrows from the Chandragiri Municipality, Nepal, to further our understanding of pangolin ecology and improve its conservation.

2. Materials and Methods

2.1. Study Area

The Chandragiri Municipality (27°43′36.49″–27°32′45.03″ N, 85°16′39.51″–85°11′8.68″ E) is in southwest Kathmandu District, Bagmati Province, Nepal (Figure 1) and comprises 43.9 km^2. It has a human population of 136,928 (3118 people/km^2; [34]). It has predominantly hilly terrain with elevations from 1310 to 2551 m above sea level. It contains 23 community forests covering 1171 ha. The vegetation is mixed forest and includes the Nepalese alder (*Alnus nepalensis*), needlewood (*Schima wallichii*), chinkapin (*Castanopsis tribuloides*), pine (*Pinus roxburghii*), oak (*Quercus* spp.), rhododendron (*Rhododendron arboretum*), Himalayan ash (*Fraxinus floribunda*), and marking nut (*Semicarpus anacardium*). Major mammal species include the large Indian civet (*Viverra zibetha*), yellow-throated marten (*Martes flavigula*), jungle cat (*Felis chaus*), golden jackal (*Canis aureus*), Chinese pangolin (*Manis pentadactyla*), hoary-bellied squirrel (*Callosciurus pygerythrus*), leopard cat (*Prionailurus bengalensis*), leopard (*Panthera pardus*), and wild boar (*Sus scrofa*) [35].

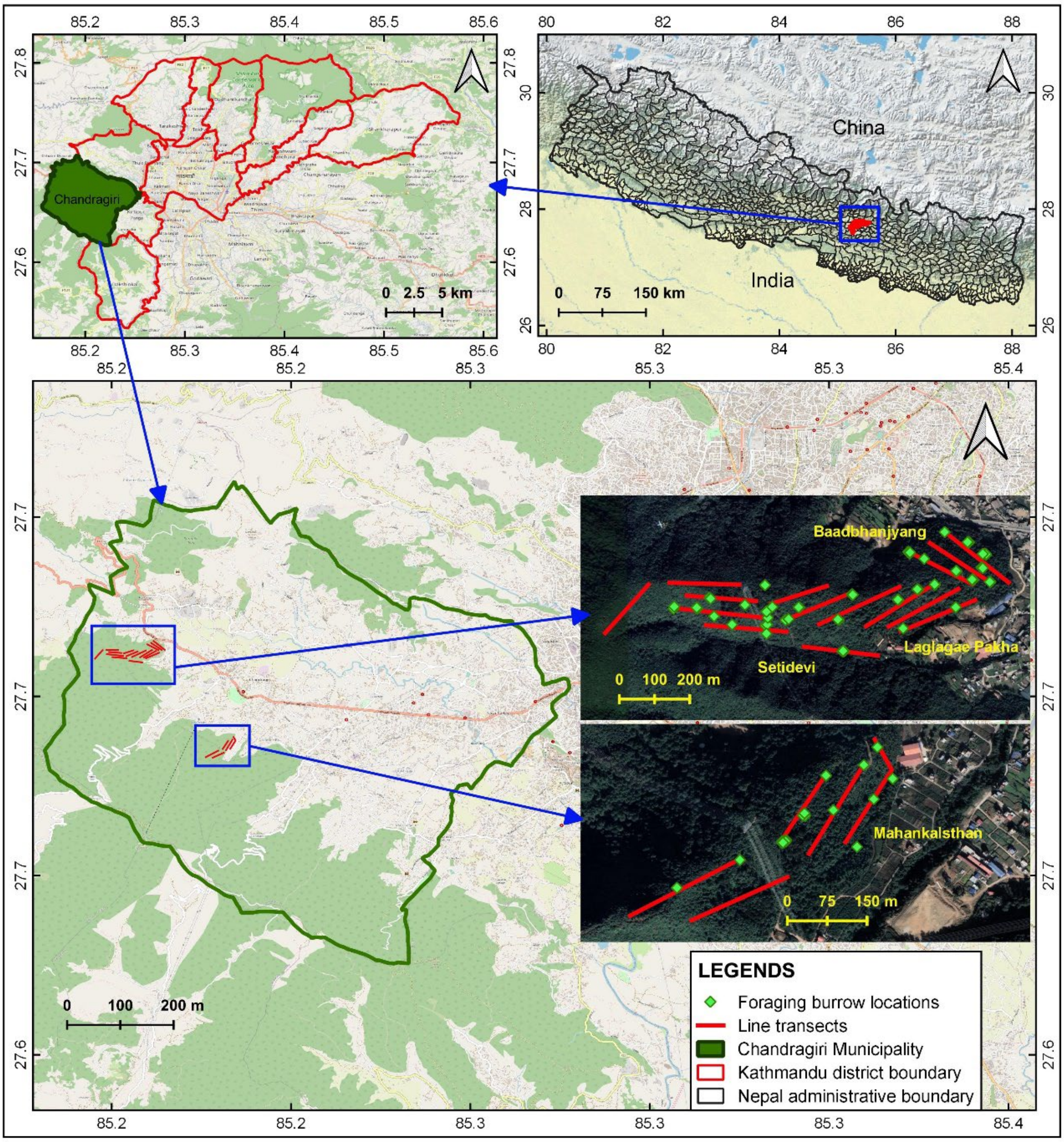

Figure 1. Chinese pangolin study area with established line transects and foraging burrows in Chandragiri Municipality, Nepal.

2.2. Methods

We conducted our field survey from November 2021–March 2022 within the Mahankal, Setidevi, Laglagae, and Baadbhanjyang community forests in the Chandragiri Municipality. Within each forest we established five transects (20 total) about 300 m long and established five, 10 × 10-m plots on each transect at 50-m intervals (Figure 1). We established a total of 100 survey plots on the 20 transects. In each plot, we recorded the foraging burrow occurrence, collected the fecal samples observed, and measured eight habitat covariates. We counted the number of ant nests and termite mounds within each plot and measured the distance from the plot center to the nearest nest or mound. We estimated the slope gradient using a clinometer at the plot center. We estimated canopy coverage by averaging values obtained at the plot center and the four corners using a spherical densiometer. We counted the number of trees (>5-cm diameter at breast height and >1.5-m tall) in each plot. We then measured the distance from the plot center to the nearest road, water source (e.g., stream, pond), and agricultural land; distances <25 m were measured using a tape measure, with greater distances estimated using Google Earth Pro.

We collected Chinese pangolin fecal samples opportunistically from burrow openings to estimate diet composition, placing each in a plastic bag with desiccant before analyses. We identified fecal samples from the Chinese pangolin by visual observation and by detecting the presence of chitin fragments in the feces [36].

In the laboratory, we placed samples in 70% ethanol and separated items manually, and then used a stereomicroscope for identification. We identified prey to the lowest taxonomic level using keys for ants [37], termites [38], and other invertebrates, as well as a reference collection obtained during our surveys in the study area.

We used a generalized linear mixed model to identify factors affecting the occurrence of the Chinese pangolin in the Chandragiri Municipality in 2021. Factors include elevation (m), slope gradient (°), forest canopy cover (%), distance to a water source (m), roads (m), settlements (m), agricultural land (m), ant nests (m), no. of ant nests, and tree abundance. Elevation and distance to settlement were highly correlated variables ($|r| > 0.7$) with distance to agricultural land, and we retained the latter for analysis (Figure 2). We rescaled continuous variables from 0 to 1 before analyses. We used R program for analyses [39]. Means are reported with a +1 standard error (SE).

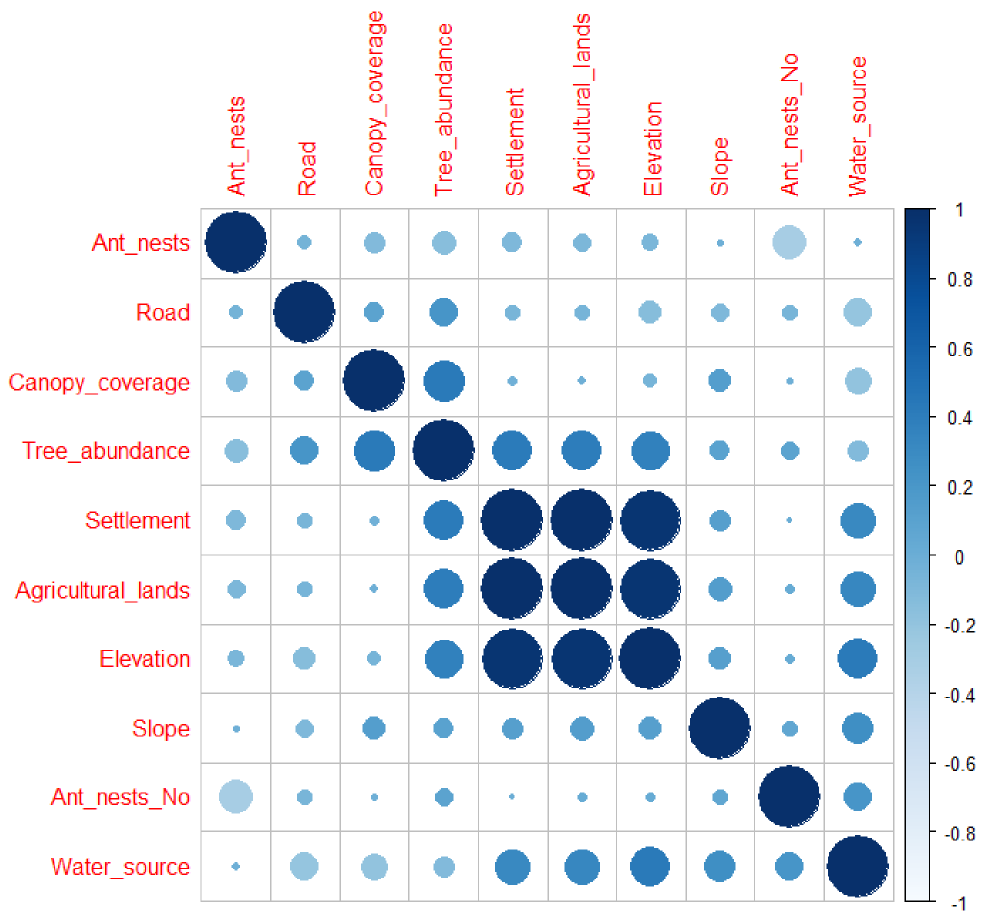

Figure 2. Correlation matrix between predictive variables to estimate factors influencing Chinese pangolin foraging burrow occurrence in Chandragiri Municipality, Nepal. Variables Ant_nests = distance to nearest ant nest, Road = distance to nearest road, canopy_coverage = % forest canopy coverage, Tree_abundance = number of trees, Settlement = distance to nearest settlement, Agricultural_land = Distance to nearest agricultural land, Ant_nest_no = number of ant nests and water_source = distance to nearest water source.

3. Results

We identified 88 foraging burrows in the 38 surveyed plots; 30 (34%) in the Mahankalsthan, 15 (17%) in the Setidevi, 24 (27%) in the Baadbhanjyang, and 19 (22%) in the Laglagae Pakha community forests. We located burrows 1450 to 1800 m above sea level [(average 1585 ± 11.6 m (SE)] with most burrows (81.8%, *n* = 81) within 1500–1700 m elevation (Table 1). Most burrows (46.5%, *n* = 46) were recorded on 30–40° slopes (Figure 3). Most burrows (61.4%, *n* = 54) were under 50–75% forest canopy coverage (Figure 4). The average distance to the nearest road from the center of the plot was 28.1 ± 0.9 m (range = 1 to 272.3 m), and most burrows (88.6%, *n* = 78) were <100 m from the nearest road. Most burrows (55.6%, *n* = 55) were <100 m from the nearest water source. The average distance to agricultural lands was 224 ± 28.2 m (range = 55–1025 m) with most burrows (78.8%, *n* = 78) recorded within 400 m of agricultural lands (Figure 5). The average distance to the nearest ant nest or termite mound from the center of plots was 5.4 ± 1.3 m (range = 0.6–38 m) with most burrows (72.7%, *n* = 72) within 20 m (Figure 6).

Table 1. Habitat variables for sites with (*n* = 38) and without (*n* = 62) Chinese pangolin foraging burrows, Chandragiri Municipality, Nepal.

Variable	With Burrow			Without Burrow		
	Mean	**SE**	**Range**	**Mean**	**SE**	**Range**
Elevation (m)	1585	11.6	1461–1737	1610	15.3	1454–1886
Slope (°)	28.1	0.9	16–40	24	1.1	8–40
Forest canopy coverage (%)	66.8	2.5	1.5–80.8	65.8	1.6	12.2–82
Distance to road (m)	40.8	8.8	2–272.3	18.5	6.4	1–239.7
Distance to water (m)	93.3	14.1	5.5–376.9	73.1	16.9	1.8–536.5
Distance to settlement (m)	284.3	26.2	50–939.8	233.7	35.4	47.3–656.6
Distance to agricultural lands (m)	245	28.2	57.8–694.6	329.2	37.3	63.8–1024.8
Number of ant nests	1.6	0.2	1–8	1	0.1	1–4
Distance to ant nest (m)	5.4	1.3	0.6–38	10	1.6	0.5–48
Tree abundance	13.1	1.03	1–29	12.5	0.7	3–27

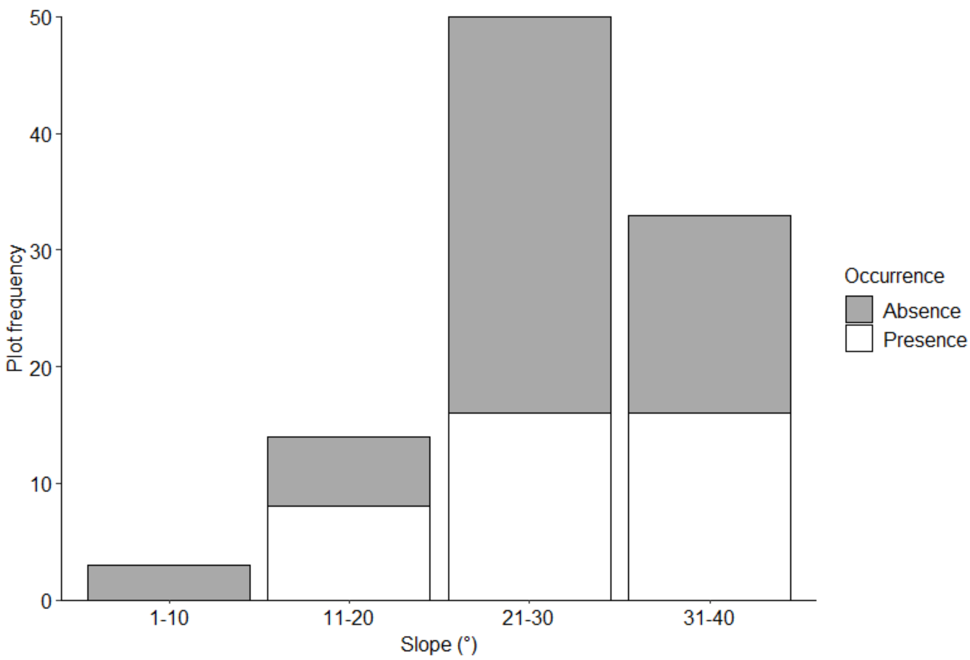

Figure 3. Chinese pangolin foraging burrow distribution by slope gradient in Chandragiri Municipality, Nepal.

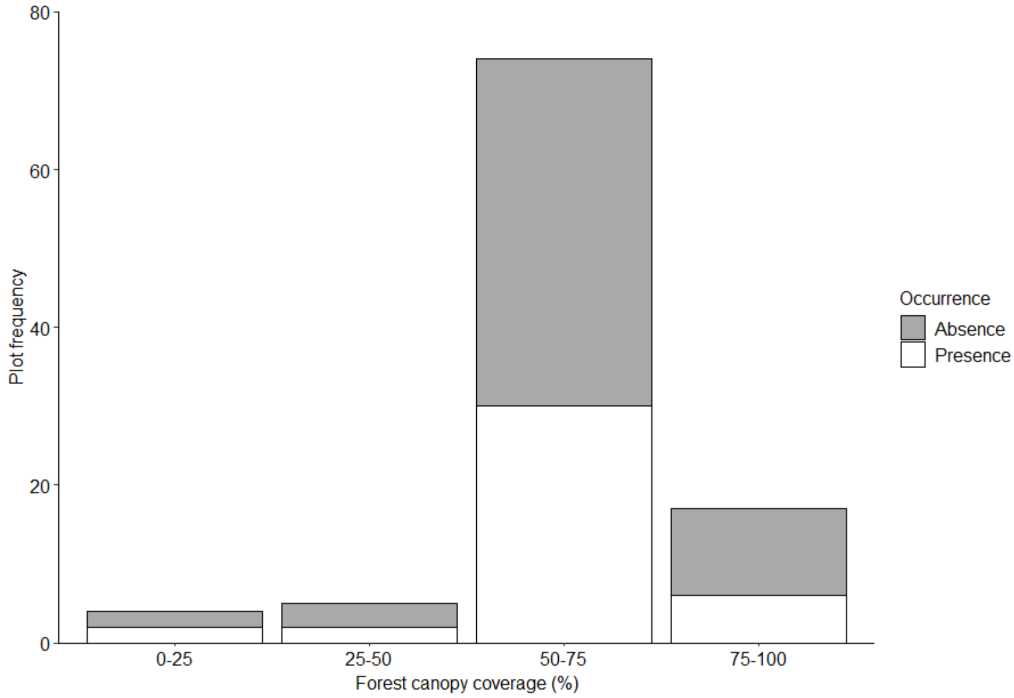

Figure 4. Chinese pangolin foraging burrow distribution by forest canopy coverage in Chandragiri Municipality, Nepal.

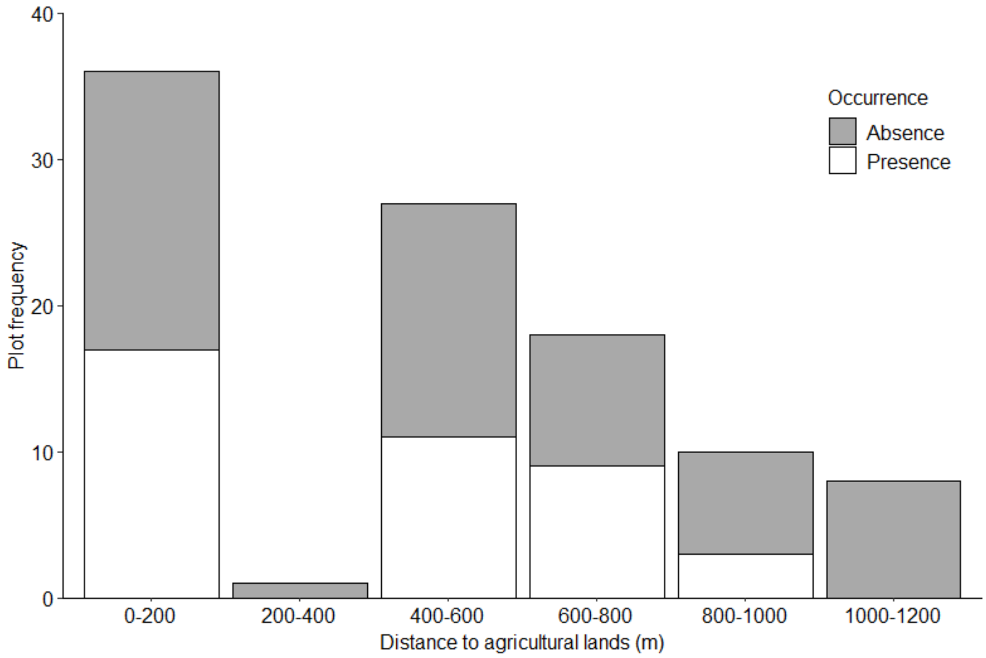

Figure 5. Chinese pangolin foraging burrow distribution by distance to agricultural lands in Chandragiri Municipality, Nepal.

The probability of detecting a Chinese pangolin foraging burrow was greater with increasing slope and decreased with increasing distance to agricultural lands and ant nests or termite mounds (Table 2). No other variables measured were significant.

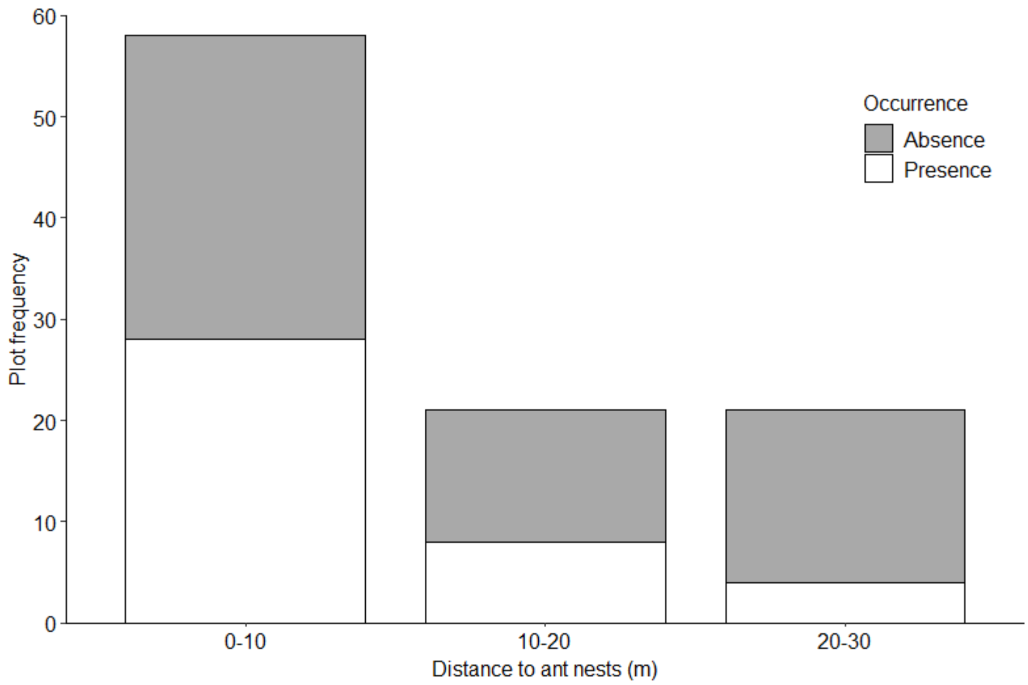

Figure 6. Chinese pangolin foraging burrow distribution by distance to ant nests in Chandragiri Municipality, Nepal.

Table 2. Generalized linear mixed model estimates and 95% confidence limits describing the Chinese pangolin occurrence in Chandragiri Municipality, Nepal. Variables include slope gradient (°), forest canopy coverage (%), distance to water source (m), road (m), agricultural land (m), and ant nests (m), no. of ant nests, and tree abundance were included in model construction. Significant effects ($p < 0.05$) are in bold.

Variables	Estimate	Standard Error	Z-Score	*p*
(Intercept)	0.928	1.297	0.716	0.474
Slope gradient (°)	2.612	1.117	2.338	**0.019**
Forest canopy coverage (%)	−3.260	1.640	−1.988	**0.047**
Distance to road (m)	1.483	1.198	1.238	0.216
Distance to water source (m)	−0.291	1.384	−0.210	0.834
Distance to agricultural land (m)	−3.224	1.180	−2.731	**0.006**
Distance to ant nest (m)	−2.720	1.203	−2.261	**0.024**
Number of ant nests	1.099	1.869	0.588	0.557
Tree abundance	2.385	1.504	1.586	0.113

We collected 10 Chinese pangolin fecal pellets. The prey species detected were comprised solely of invertebrates including *Aphaenogaster symthiesii*, *Camponotus* sp., *Monomorium* sp., *Pheidole* sp., beetles, soil mites, a bug, a mole cricket, and an unidentified pupa (Figures 7–9).

Figure 7. Ant body parts found in the fecal samples of the Chinese pangolin in Chandragiri Municipality, Nepal.

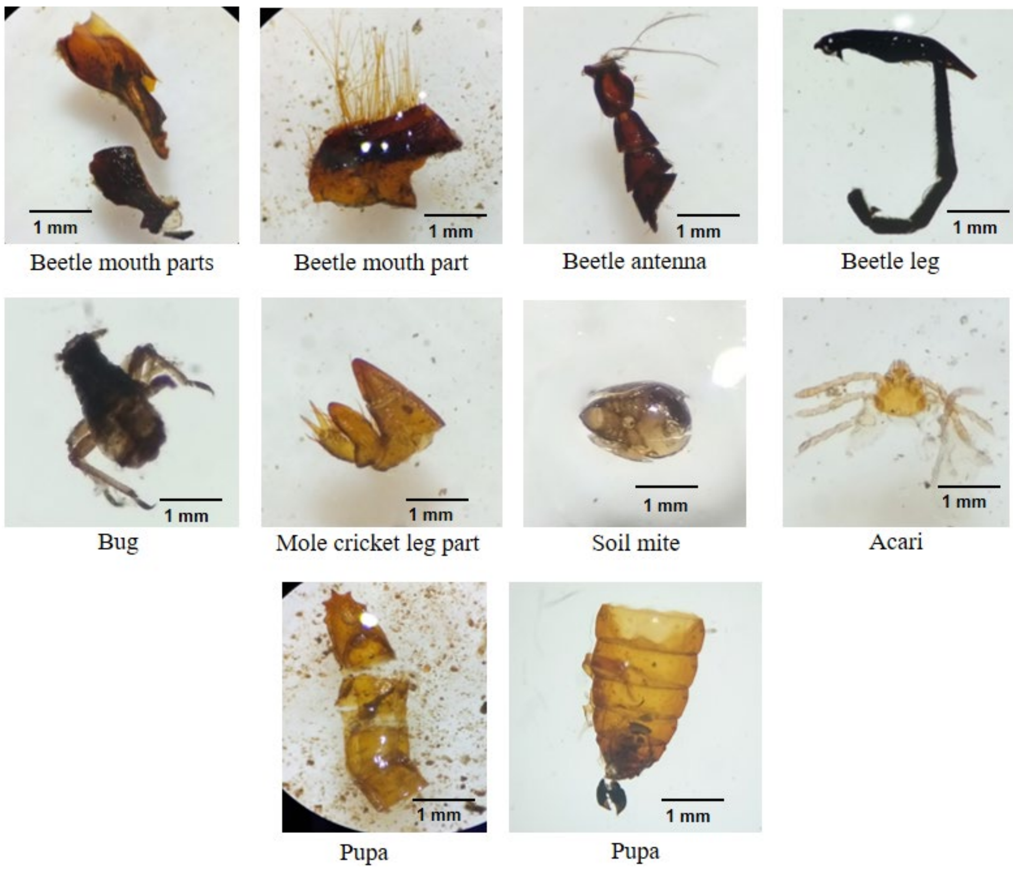

Figure 8. Insect body remains from fecal samples of Chinese pangolins in Chandragiri Municipality, Nepal.

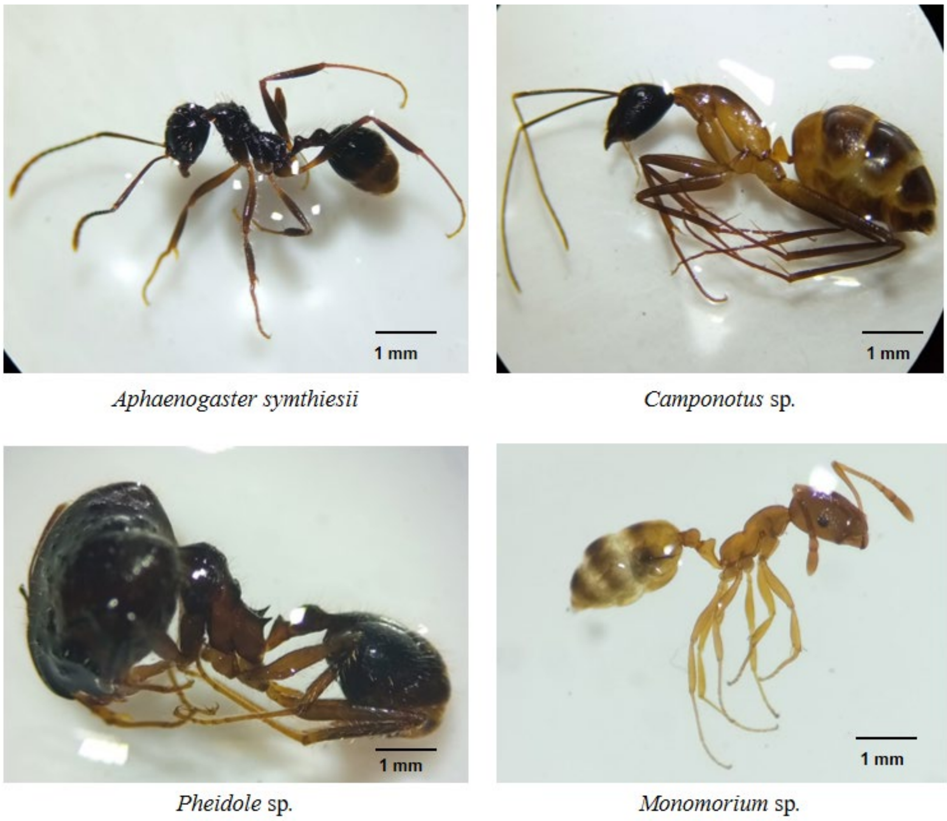

Figure 9. Major ant species present in the diet of Chinese pangolins in Chandragiri Municipality, Nepal.

4. Discussion

The occurrence of Chinese pangolin foraging burrows was influenced by slope gradient, distance to agricultural lands, and distance to ant nests. The presence of burrows on slopes of 30–40° suggests moderately steep slopes are more suitable for foraging. Steeper slopes (30–60°) could maintain stable temperatures inside burrows and ensure the availability of termites [40], whereas the absence of burrows in slopes >60° could be due to reduced food availability and accessibility [12,40,41]. Moderately steeper slopes could also ensure the stability and integrity of burrows by reducing erosion and facilitate their excavation [40].

We found that canopy cover influenced pangolin burrow presence; that most burrows occurred in forests with 50–75% canopy coverage suggests that Chinese pangolins opt for intermediate to higher levels of canopy cover, as reported previously [9]. Chinese pangolins have poor defenses against predators [42], and a greater canopy cover could reduce predation risk [43]. Chinese pangolins have a poor capacity to adapt to changing temperatures, and denser canopy cover may also buffer against fluctuations in ambient temperature [40]. Additionally, ants and termites are more abundant and diverse in areas with denser forest canopies [44,45]. Finally, forests with denser canopies have less understory vegetation which could facilitate pangolin movements [46].

The occurrence of Chinese pangolin foraging burrows was greater nearer to agricultural areas, but the distance to water and roads did not influence burrow occurrence. Agricultural lands are abundant with ants and termites due to the presence of plant debris and animal dung [47]. However, anthropogenic activities such as the collection of fuel wood and fodder, livestock grazing, and the use of pesticides can cause disturbance and decreased prey availability for pangolins [15]. Moreover, pangolin activity near agricultural or other areas of human activity could increase their risk of being hunted [48]. The lack of relationship between the distance to water and burrow occurrence could be a consequence of the prevalence of water in the study area. Pangolins use water sources frequently and ants, termites, and other insects often select moist habitats [49,50]. We suggest that the abundance of water sources in our study area alleviated the need for the spatial selection of this resource.

The greater presence of Chinese pangolin foraging burrows near ant or termite mounds is undoubtedly a consequence of their myrmecophagous diet [12,43]. Burrows appear to be excavated near food sources [HPS personal observation] which would reduce energy expenditure when foraging [51]. Chinese pangolins feed almost exclusively on ants and termites with occasional feeding on other invertebrates. The presence of only four ant species (*A. symthiesii*, *Camponotus* sp., *Monomorium* sp., and *Pheidole* sp.) in the fecal samples despite that 15 ant species were collected from the study area as references suggest that the Chinese pangolin may exhibit selection among ant species. Several reasons could explain the species consumed: (1) pangolins may feed on the most available species; (2) pangolins may opt for larger (>5 mm body length) species. Larger ants could increase foraging efficiency and provide more energy and nutrients than smaller-sized prey [26]; and (3) pangolins may prioritize easy-to-capture prey [25,28]. Ant species recovered from scats in this study nest just below the soil surface or in decomposed logs which can be readily obtained by pangolins, particularly juveniles [28].

The selection of the ant species consumed might also be due to the chemical and mechanical defenses of the prey species; pangolins avoid ant and termite species with well-developed defense systems [52]. Ant species in the subfamily Ponerinae have strong defenses against predators [28], which could explain the avoidance of Ponerinae species such as *Brachyponera* and *Ectomomyrmex* by the pangolins. Previous studies suggest that pangolins prefer ants over termites [23,25–27] for reasons including difficulty accessing termites from mounds [41], which may partially explain why termites were not detected in Chinese pangolin fecal samples in this study. However, the complete digestion of termites that are relatively soft-bodied compared to ants could have limited our ability to detect them [53].

5. Conclusions

The foraging habitat selection of Chinese pangolins was influenced by slope and apparent food availability. Chinese pangolins may exhibit prey selection, but larger studies quantifying prey use and availability are required. Our study provides baseline data on the foraging habitat use and diet that could benefit ex-situ conservation efforts as well as captive breeding programs for Chinese pangolins. Furthermore, this information can be used to aid site-specific management plans in Nepal to protect or improve habitat suitability for Chinese pangolins.

Author Contributions: Conceptualization, S.T. and H.P.S.; Data collection, S.T.; Supervised, H.P.S.; Data Analyzed, S.T. and H.P.S. writing—original draft preparation, S.T. and H.P.S. writing—review and editing, S.T., H.P.S. and J.L.B. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: Not Applicable.

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Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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Conflicts of Interest: The authors declare no conflict of interest.

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