Assessing mammal diversity, distribution, and abundance: piloting arboreal camera trapping as a tool for monitoring endangered red panda in temperate forest of Eastern Nepal

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Sonam Tashi Lama

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Assessing mammal diversity, distribution, and abundance: piloting arboreal camera trapping as a tool for monitoring endangered red panda in temperate forest of Eastern Nepal

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I investigated the diversity, abundance and terrestrial activity patterns of medium and large sized wild mammals including a dedicated camera trapping survey for endangered and arboreal red pandas in the non-protected forests of Ilam, Panchthar, and Taplejung districtss of eastern Nepal. This thesis presents the first camera trap-based inventory of the southern Kangchenjunga region. The mammalian inventory was done during the winter and spring season of 2018 with 107 different camera trap locations (53 in winter and 54 in spring).

The dedicated camera trapping survey for red panda camera was conducted in 19 different locations of Ilam and Panchthar districts using a pair of camera traps at each site (one on ground and one in tree canopy). There were 903 photographs (96 from ground camera and 807 from arboreal camera) of red panda from 1,620 camera trap days.

Over 3,014 camera trap days there were 93,336 photographs taken (5,176 of wild mammals, 3,621 of birds, 11,692 of people, and livestock, 65,488 of false triggers and 6,061 during camera set ups). 5,177 photographs of medium to large sized mammals were used for the analysis in Camera Base. There were 17 species of medium to large sized wild mammals observed belonging to 4 orders and 12 families. Notable species records from this study were red panda *Ailurus fulgens,* common leopard *Panthera pardus,* marbled cat *Pardofelis marmorata,* Asiatic golden cat *Catopuma temminckii,* Himalayan serow *Capricornis thar,* Himalayan goral *Naemorhedus goral,* Assam macaque *Macaca assamensis,* Himalayan black bear *Ursus thibetanus,* and Spotted linsang *Prionodon pardicolor.* The leopard cat *Prinonailurus bengalensis* was found to have the most diverse distribution covering temperate to alpine habitat. The Northern red muntjac *Muntiacus vaginalis* was found to be the most abundant species followed by wild boar *Sus scrofa,* leopard cat, and red fox *Vulpes vulpes.*

Despite some limitations, camera trapping was found to be effective in monitoring medium to large sized mammals in this study, particularly for red panda. Employing camera trap surveys for similar kinds of studies, and also for the long-term monitoring of mammals in a study area, is recommended for management of wildlife and effective conservation.

Keywords: Camera trapping, Nepal, red panda, *Ailurus fulgens,* temperate forest, Eastern Himalaya, mammal diversity, endangered, mammal inventory, mammal diversity, arboreal camera trapping

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Chapter 1

Introduction

1.1 Background

Nepal, with a variety of physiographic features, contains the world's highest terrestrial ecosystem as well as subtropical plains as low as 60 m of altitude. Nepal is home to 208 mammal species (Baral and Shah 2008, Jnawali et al. 2011). The latest checklist of the mammals of Nepal by Thapa (2014) only mentioned 192 species, omitting previously listed species with some meaningful basis of reference. Of the four newly added mammal species, three are cat species. The newly recorded mammal species for Nepal includes a Rusty-spotted cat (Lamichhane et al. 2016), Pallas's cat (Shrestha et al. 2014), Steppe Polecat (Chetri et al. 2014), and Ruddy Mongoose (Subba et al. 2014). Of the documented 208 mammal species (Jnawali et al. 2011), one species was categorised as Regionally Extinct, eight were Critically Endangered, twenty-six were Endangered, fourteen were Vulnerable, and seven were Near Threatened in the National Red List Assessment. The terrestrial mammals with their huge taxonomic diversity and utilisation of a vast range of ecological niches are an indicator of environmental impacts on the Earth's biota (Ceballos and Ehrlich 2002). The mammalian biota also has an important role in the functionality of the ecosystem (Ripple et al. 2015). The information on the status of wild mammals has value as it provides crucial information on the natural history of species, which helps to inform the decision makers in conservation and influence policy (Amin et al. 2018).

In Hindu Kush Himalaya, an important transboundary landscape, the Kangchenjunga Complex is shared by Bhutan, China, India, and Nepal. The southern portion of the Kangchenjunga complex, which extends across eastern Nepal, Darjeeling, and Sikkim of India, and western Bhutan is known as the Kangchenjunga Landscape (KL) (Chaudhary et al. 2015). The part of the KL in eastern Nepal is also a part of the Sacred Himalayan Landscape (SHL) (GoN/MoFSC 2016) with transboundary conservation importance to China and India. It offers a home to a wide range of endangered fauna and flora (CEPF 2005, Chettri et al. 2007). It falls under the Eastern Himalayas region, a Global 200 ecoregion (Olson and Dinerstein 1998), and is also a global biodiversity 'hotspot' (Dinerstein et al. 2017). High biodiversity and endemism are characteristics of the Eastern Himalayas region (Myers et al. 2000). The Kangchenjunga landscape holds 14 protected areas, including the Kangchenjunga Conservation Area (KCA) on the Nepal side of the border and Khangchendzonga Biosphere Reserve (KBR), Singhalila National Park (SNP), & Barsey Rhododendron Sanctuary (BRS) in the Indian side (Rana 2008). KCA is the only protected area of KL in Nepal. Illegal hunting and poaching, illegal trade of wildlife and their products, transboundary migration of the wildlife populations are part of management problems in transboundary biodiversity management (Basnet 2003).

The landscape extending from KCA in Nepal to KBR in Sikkim in India includes the forest patches of Ilam and Panchthar districts in Nepal (CEPF 2005). In the Kangchenjunga-Singhalila complex, the forest patches of Ilam, Panchthar, and Taplejung districts are non-protected areas are under the management of Division Forest Offices (DFOs). Often these DFOs lack proper management due to the various components along with high pressure on forest resources (Chaudhary et al. 2015). Poaching and illegal wildlife trade are also the part of the threats to the faunal communities of the landscape. The patches of forest in Ilam, Panchthar, and Taplejung districts are also important as they provide the connectivity to the protected areas of Nepal and India. The eastern subtropical and temperate forests of Ilam and Panchthar districts also connects the tropical broadleaf forest of Jhapa district, in the south of Ilam to the multiple forest types of KCA in eastern Nepal (Yonzon 2000).

The unprotected forest areas of Ilam, Panchthar, and Taplejung districts fall in the southern part of the KL, harbouring important species diversity and are proposed as one of the six corridors (Eastern Nepal Conservation Corridor, in buffer areas of KBR, BRS, and SNP in India), maintaining connectivity in the KL. Scattered and isolated reserves alone are not sufficient for conserving nature (Sharma and Chettri 2005, Chettri et al. 2008, Shakya and Joshi 2008). In this proposed corridor, only 24% of the area falls inside the temperate mixed forest, and humans use alpine meadows whereas 46% of the area in the form of settlement, and other proposes of agricultural activities signifying huge human foot-prints and anthropogenic impact in the area (Shakya and Joshi 2008). There is a loss of goods and ecosystem services and indicates a considerable threat to the diversity of species (Ceballos and Ehrlich 2002).

According to Shakya and Joshi (2008), there are 22, 42, 22, and 26 mammalian species in KCA, KBR, BRS, and SNP of KL that surround the study area, respectively. The Upper Mai Valley Forests of Ilam district are important for mammals and bird communities of threatened species and fall under an Important Bird Area (IBA) (Baral and Inskipp 2005) that connects to another IBA of eastern Nepal - Tamor Valley.

Over 80 mammal species are known to occur in the SHL. These include several large, charismatic and focal species for conservation, notably the snow leopard *Uncia uncia*, red panda *Ailurus fulgens*, musk deer *Moschus chrysogaster*, Tibetan wolf *Canis lupus chanco*, blue sheep *Pseudois nayaur*, Himalayan thar *Hemitragus jemlahicus,* and clouded leopard *Neofelis nebulosa* (Gurung et al. 2006, Sharma 2008). Among 255 identified resident terrestrial mammal species in Eastern Himalayan region, 53 (21%) are globally threatened (4 Critically Rare, 23 Endangered and 26 Vulnerable). Only 13 (5%) species are data deficient, and the same number of species are endemic to the eastern Himalayan region (Dorji et al. 2018). The data deficient species are always at risk of becoming threatened when adequate data are collected (Bland et al. 2015). CEPF (2005) had identified 32 mammal species in the Eastern Himalayan region of Nepal as Globally Threatened (Critically Endangered, Endangered and Vulnerable) including the red panda, Assamese macaque *Assamese macaque*, clouded leopard, Himalayan thar, wild dog *Cuon alpinus*, and Asiatic black bear *Ursus thibetanus*. Some of these species require extensive habitat areas with high-quality corridor linkages between the habitats for their survival (Chettri et al. 2007). Knowledge of wildlife diversity in these areas either is from the protected areas only or based on anecdotal reports or community consultation. Despite being a biodiversity-rich area, the unprotected areas of the Ilam, Panchthar, and Taplejung districtss in eastern Nepal have had no scientific survey on their mammalian assemblage. This is also the case for the whole Eastern Himalayan region. While designing the proper strategies and policies on conserving biodiversity, these substandard baseline data serve as an impediment. Eastern Nepal has high endemicity on species richness (Dorji et al. 2018), but there was a shortfall of the information on distribution and status for most of the species (Chaudhary et al. 2015). This shortfall has impeded to development of the Eastern Himalayas profile. Additionally, the lack of information highlights the need for an assessment of species diversity and distribution in the non-protected areas of eastern Nepal.

Due to the remote, isolated, rugged, and difficult physiographic setting of the Himalayas, an estimate of biodiversity in the area is incomplete. An assessment of the area's wildlife diversity, through camera trapping, would provide some crucial data in the aspect of ecology and behaviour of species. Yonzon (1996) recommended a detailed assessment of biodiversity in the Kangchenjunga region for the development of a conservation management plan. Despite scientific study in Kangchenjunga beginning in the 1940s, with targeted research of particular species in the Eastern Himalayas, mostly in India (91%), there is a lack of systematic research on the ecological aspects of species (Kandel et al. 2016).

The transhumant herding of yak, *dzos* (hybrid of yak and cow), cow and sheep in larger herds, intensification of agriculture, and unsustainable harvesting of fuelwood, fodder, and timber are prevalent across the Nepalese Himalaya as well as eastern Nepal (CEPF 2005, Oli 2008). Tea plantations were introduced to the region and commercial agriculture is concentrated in the eastern region of the Himalayas because of the proximity to Calcutta and other ports on the Bay of Bengal (English 1985). Market incentives have resulted in the land-use of eastern Nepal being heavily market-driven, threatening habitat of the red panda and other mammals, where agricultural grazing has been practised for at least 160 years (Hooker 1889, Oli 2008). All of these activities have resulted in a decrease of the forest coverage in the area and created fragmentation of the habitat, increasing threats to the several endangered species, including red panda (Oli 2008). The faunal diversity of Kangchenjunga landscape is also threatened by other factors like poaching and illegal trade (Chaudhary et al. 2015).

1.2 Wild mammals of eastern Nepal, and their study

The checklist of the mammal species of eastern Nepal is based mainly on anecdote. Information on the composition of the medium and large sized terrestrial mammals in the present study area of Ilam, Panchthar, and Taplejung is scarce or unknown. The area is important as it connects the protected areas of India and Nepal as a corridor and lacks proper conservation and management actions. A recent study by Dorji et al. (2018) stated that eastern Nepal has high endemic mammals richness. It lies in the adjoining parts of the highest species richness areas, like Sikkim and north of West-Bengal.

The first European known to travel and record diversity in eastern Nepal was Sir Joseph Dalton Hooker from October through December 1948 (Hooker 1889). Four bird and animal shooters, a collector and a taxidermer of Hodgson (a naturalist and former British resident of northern India and Nepal) also accompanied Hooker's team. During his expedition, he travelled into my study area and all the high altitude passes into Tibet, including the Olangchung, Yangma, Khambachen, and Yalung Vallies. Hooker mentioned sighting a few wild animals in his Himalayan journal. These included hornbill *Buceros bicornis* around Sakhejung Ilam, otters in Taplejung, a chameleon, and a porcupine in Lelep (KCA), a herd of twenty five argali *Ovis ammon* in Yagma Valley, shooting of a pair of Kalij pheasant by his Lepcha assistant, a pair of musk deer *Moschus* sp. at 13,290 feet in Yalung Valley and a troop of monkeys in Panchthar. In the recent times, the argali has been reported from western Nepal (Mustang, Dolpa, and Humla) only (Kusi et al. 2018). Similarly, the *Buceros bicornis* has been wiped out from the area.

Biswas and Khajuria (1955) collected mammals from the Khumbu (Everest) region of eastern Nepal. They described the two species and two subspecies of small mammals for the first time. Later, they reported a list of mammals of eastern Nepal (Biswas and Khajuria 1957). Similarly, the German-Nepal Himalaya Expedition listed 14 species from 10 genera of insectivores and rodents from eastern Nepal (Weigel 1969). Johnson et al. (1980) conducted a mammal survey in Biratnagar, Dharan, Dhankuta, Chainpur, Mangalbare, Terathum (Chitre) in eastern Nepal. They recorded many species including *Mus* and *Rattus* and other notable records such as *Sus scrofa, Petaurista magnificus, Martes flavigula, Herpestes auropunctatus,* and *Paradoxurus hermaphroditus*. This survey did not cover the areas of my study and was not an intensive survey of all of Nepal.

Shrestha (1989) reported a large collection of mammals, birds, reptiles, and insects in Makalu-Barun area by the Arun Valley Wildlife Expedition during 1970-1973. The Makalu Barun is in west of the Kangchenjunga landscape. A camera trapping study by Ghimirey (2010) recorded seventeen species of mammals from the Makalu Barun National Park. The first photo record of a melanic Asiatic golden cat was made in this study. Additional twelve species of mammals were recorded with direct observation and pelt records in the area by latter.

Twenty-two species of mammals were reported from KCA of eastern Nepal (Shakya and Joshi 2008). Research on snow leopard *Panthera uncia* and dhole *Cuon alpinus* has been done in KCA (Khatiwada and Chalise 2006, Khatiwada et al. 2011, Subba et al. 2017). Currently, WWF Nepal monitors snow leopards through satellite collaring in KCA (WWF 2017). Only four mammals, Yellow throated marten *Martes flavigula,* jungle cat *Felis chaus,* Royle's pika *Ochotona roylei,* and blue sheep *Pseudois nayaur,* were recorded by Carpenter et al. (1994) through direct observation in KCA. On the next year, they listed 19 mammal species in KCA through consultation with the local people and observations of wildlife scats (Carpenter et al. 1995). They listed some notable mammal species, such as pangolin *Manis pentadactyla,* snow leopard *Panthera uncia,* Himalayan black bear *Slenarctos thibetanus,* Himalayan thar *Hemitragus jemlahicus,* wild yak *Bos mutus* (Carpenter et al. 1995). The presence of wild yak is only recorded from Humla, far-western Nepal (Acharya et al. 2016). Chaudhary et al. (2015) reported 102 species of mammals and 354 species of birds in the KL in Nepal. Their report was based on a review of the past literature. Among them, 15 species were protected by the National Parks and Wildlife Conservation Act 1993. Nearly half of the total species are mentioned as not evaluated or data deficient on the Nepal Red List (Jnawali et al. 2011) demanding more study on their ecology, biology and distribution. Long-term monitoring of red panda in eastern Nepal has been conducted by Red Panda Network for more than a decade (Williams et al. 2011).

The mammalian diversity in the proposed and unprotected corridor, which is the study area of my research in eastern Nepal, is undocumented. Knowledge of species occurrence, composition, distribution, and activity pattern in the area is lacking. A camera trap based inventory of terrestrial mammal of eastern Nepal will obtain reliable information on the natural history of species in the study area, which will support in the planning and execution of the efficient and effective wildlife conservation and management and human-wildlife conflict mitigation programs in future.

1.3 Human-wildlife conflict in eastern Nepal

The poaching of wildlife by humans and wildlife browsing of crops and depredation on livestock has been reported from the protected areas throughout the KL (Oli et al. 2013). This kind of relationship creates conflict between humans and wildlife. Barking deer, Himalayan black bear, snow leopard, and common leopard are the main wildlife species that cause these interactions in the area. In the lowlands of KL, there is also a problem of seasonal migration by herds of elephants.

Conflict between humans and Assam macaques was reported from the Makalu-Barun National Park. The damage to the major cash crop of the area, the large cardamom, by Assam macaques is considerable (Ghimirey et al. 2018). Retribution killing of macaques is prevalent in the area. The level of conflict increases with felid body mass although there are no reports of attacks on humans by snow leopards (Inskip and Zimmermann 2009).

The status and trends of human-wildlife conflict in eastern Nepal have only been documented from the KCA and Jhapa districts of eastern Nepal (Khatiwada et al. 2011, Chaudhary et al. 2015, Sherchan and Bhandari 2017). Snow leopards and wild dogs are reported to be the major predator of livestock by Sherchan and Bhandari (2017). Similarly, they reported civets, barking deer, porcupines, squirrels, monkeys, and black bears to be responsible for the most damage to crops in KCA. The people of KCA have practiced alternative cropping of medicinal plants, such as *Swertia chiraita,* to mitigate crop damage by wildlife. The predation of livestock by snow leopards and wild dogs is more common in Ghunsa Valley (Sherchan and Bhandari 2017) and Yamphudin village of KCA (Khatiwada et al. 2011), respectively. A livestock insurance scheme has been in practice in KCA since 2005, and the occasional retribution killing of snow leopards by the local herders has been limited since then (Gurung et al. 2011). But the premium and relief amounts were recommended for revision by Sherchan and Bhandari (2017) due to the very minimum cover compared to the actual value of their livestock. The conflict of snow leopards with humans is well documented throughout the leopard's range (Inskip and Zimmermann 2009) and is no different in Nepal.

1.4 Red Panda Network

The Red Panda Network (RPN), initiated as the Red Panda Project in 2006, has been conducting community-based red panda conservation, research, education, and community livelihood support programs in eastern Nepal (Williams et al. 2011). Initially, RPN started to work in the Panchthar-Ilam-Taplejung (PIT) Corridor in eastern Nepal. RPN hires, trains, and mobilises local community people, named as forest guardians (FG) for the long-term monitoring of endangered red panda and sympatric species for research and mitigating illegal poaching. Currently, there are 73 FG engaging 49 community forest user groups in the PIT-Corridor (Bista 2018). RPN's community-based red panda conservation program in eastern Nepal was the first of its kind throughout the entire red panda range countries. The long-term goal of RPN is to create many community conserved areas dedicated for conserving red pandas as more than two-thirds of total red panda habitat in Nepal is outside the current network of the protected area system (MoFSC-Nepal 2016b). FGs are integral members of this study as they were involved in the camera trapping and data collection. This study is important as it provides the first camera-trapping based baseline data on mammals of temperate forest of eastern Nepal, which is vulnerable to diverse threats.

1.5 Mammalian inventory and study of their terrestrial activity patterns

Despite Nepal's rich biodiversity, it is still lacking the proper documentation of its faunal diversity due to the lack of adequate resources, lack of trained biologists and many rugged mountainous terrains to conduct the surveys. The assessment of the fauna is usually confined within protected areas and is conducted with the survey methods, which are mostly based on indirect sign surveys to confirm the presence or absence of a species. Inventory of the mammalian assemblage is important in understanding the distribution of species. A single method for inventorying wild mammals is not effective (Pittet and Bennett 2014) and the addition of camera trapping is one of the effective and efficient methods for surveying mammals in the Himalayas (Sangay et al. 2014).

Direct observation of wildlife in the field by a researcher has a long been a practised and tested tool for examining their behaviour and activity. The direct observation of wildlife was a prominent technique before the arrival of the radio telemetry in the 1960s (Bridges and Noss 2011). Direct observational studies in wild have been done for elephants, orangutans, and gorillas (MacKinnon 1974, Barnes 1982, Moss 1983, Breuer et al. 2005). It was also done on arboreal and shy red pandas in the rugged terrains with thick bamboo structure in the foothills of the Himalaya in India (Pradhan 1999). However, observational studies have limitations with sample sizes (Bridges and Noss 2011), labour intensiveness and resource demands.

Similarly, the use of telemetry also has limitations associated with animal trapping and handling. Although camera traps can be seen and heard by wildlife (Meek et al. 2014), less disturbance is likely to be involved than when researchers are present in the field to observe animals (Bridges et al. 2004b) directly. The camera trap data on the target species of study can also be used to express their activity patterns (Azlan and Sharma 2006, Bhattacharya et al. 2012, Liu et al. 2017). Currently, camera traps are being used in studying activity patterns in six broad categories (Bridges and Noss 2011); circadian rhythms (Azlan and Sharma 2006, Di Bitetti et al. 2006, Liu et al. 2017); nest predation (Smith 2004); foraging (Weckel et al. 2006); niche partitioning (spatial or temporal separation) and social systems (Fedriani et al. 2000); habitat and corridor use (Thapa et al. 2017); and refugia and reproduction (Bridges et al. 2004).

Red panda

The red panda, belonging to the monospecific family Ailuridae (Roberts and Gittleman 1984), is classified as globally endangered with a continually declining population (Glatston et al. 2015). It is a habitat-specialised hypocarnivore species (Wallace 2011) favouring fir-jhapra bamboo forest that makes it vulnerable if such areas undergo environmental change (Yonzon and Hunter Jr 1991). The red panda is vulnerable due to the dependency on a particular diet and because of their limited habitat range. Red panda and 13 other mammal species were used to identify potential corridors in the

Kangchenjunga landscape (Rana 2008). In the Kangchenjunga landscape, the red panda is the most studied mammal species, accounting for 15% of the total mammal studies (Kandel et al. 2016). However, the studies were mostly concentrated on the aspects of distribution, food habits, and ecology of the species in the wild Pradhan (1999), (Pradhan et al. 2001b, a, Williams 2003, Mahato 2004, Williams 2004, Rijal 2008, Kandel 2009, Williams et al. 2011).

1.6 Camera trapping: a brief history, its application, and important documentation

The history of camera trapping for wildlife photography goes back more than a century and was instigated by a gold medal winner at the Paris World Exhibition, George Shiras and is one of the fathers of wildlife photography (Kucera and Barrett 2011). His images of the nocturnal wildlife were the first images of wildlife by a camera trap in the US and Canada which were free from the human presence (Wearn and Kapfer 2017). He used a classic technique to photograph animals, using trip wires and a flashbulb. A forester in British India, Frederick Walter Champion was the person to use a trip wire and pressure plates to capture the good quality photos of wild tigers, leopards, and other sympatric animals in the foothills of the Himalaya. He successfully demonstrated that the individual tigers could be recognised through their unique stripes in camera trapped images (Athreya et al. 2014).

The credit of using the camera traps as a purely scientific technique goes to Frank M. Chapman, the curator of Ornithology at the American Museum of Natural History, as he used trip wires to assess the species on the island of Barro Colorado in Panama (Kucera and Barrett 2011). In his 'census of living', he recorded many striking animals, including mountain lions, ocelots, and white-lipped peccaries. The importance of that camera trapping is highlighted with the photo record of the white-lipped peccaries as this species is now extinct from that island (Raby 2015). Chapman also distinguished individual animals based on markings on their body and their behaviour. At that time camera traps were able to capture only one photo at a time lacking the resetting of the camera and they were not useful in extreme weather and snow.

The biggest development in camera trapping technology was the innovation of infrared triggered devices (Carthew and Slater 1991) where the camera was triggered when an animal blocked an infrared light beam. Since the late 1980s, the use of the compact camera with films combined with an active infrared trigger increased. Then Karanth (1995) and Karanth and Nichols (1998) used automated camera trap photos to identify individual tigers in Nagarhole, India and estimated their numbers using capture-recapture analysis. Later, their work was replicated by many scientists for estimating densities of tigers and other felids (O'Brien et al. 2003, Kawanishi and Sunquist 2004, Silver et al. 2004, Trolle and Kéry 2005). Camera traps can have either passive infrared (PIR) system or an active system and most of the cameras today are equipped with a PIR system (Swann et al. 2004).

Camera traps are also useful in documenting the cryptic behaviour of animals and detecting individuals from rare species. Some examples include recording an undescribed species of Sumatran striped rabbit *Nesolagus timminsi* on the Island of Sumatra (Surridge et al. 1999); documenting a critically endangered, nocturnal, poorly known bird in India, the Jerdon's courser *Rhinoptilus bitorquatus* (Jeganathan et al. 2002)*; t*he first photo record the only endemic cat in China (Sanderson et al. 2010), the Chinese mountain cat *Felis bieti* (Yin et al. 2007); the first photo record of the Pallas's cat *Otocolobus manul* in Bhutan and Nepal (Thinley 2013, Shrestha et al. 2014); highest elevation record for the tiger *Panthera tigris* (at 4,201 m a.s.l.) and for the Asiatic golden cat *Catopuma temminckii* (at 4,033 m a.s.l.) in Bhutan (Jigme and Tharchen 2011). Similarly, Holden et al. (2003) recorded the presence of the endangered Asian tapir *T. indicus* in Sumatra, where the species had never been recorded by other survey techniques. Camera traps have also been used to capture footage of animals like the snow leopard for David Attenborough's popular Earth II series (BBC 2016).

Camera trapping is a non-invasive survey method for wildlife (Swann et al. 2004, Long et al. 2012, Gregory et al. 2014) with an output of digital images with the advancement of digital camera traps to the film camera traps from the mid-2000s. The advancement provided a solution to the slow trigger time and poor resolution of photos. Camera trapping has been used widely and extensively for all kinds of wildlife species, including birds (O'Brien and Kinnaird 2008, Thornton et al. 2012), small, medium and large mammals (Karanth and Nichols 1998, Jackson et al. 2006, Schipper 2007, Aryal and Yadav 2010, Voss 2015, Mills et al. 2016) of the animal kingdom from high Himalayas (Janečka et al. 2011, Alexander et al. 2015, Alexander et al. 2016) to deserts (Gould and Harrison 2017); subarctic (Soininen et al. 2015) to Antarctic (Jones et al. 2018) and temperate, alpine forest (Sathyakumar et al. 2011a) to tropical rainforest (Tobler et al. 2008, Rovero et al. 2014) and their canopies (Whitworth et al. 2016, Bowler et al. 2017). The use of camera traps in wildlife research and monitoring varies widely from detection or presence of the wildlife species to studies of status and distribution (Bhattacharya et al. 2012, Bashir et al. 2014), diversity and activity patterns (Sathyakumar et al. 2011a, Liu et al. 2013, Liu et al. 2017, Lahkar et al. 2018), population (Karanth 1995, Karanth et al. 2006), abundance and behaviour (Liu et al. 2013), density estimation (Carbone et al. 2001, Borah et al. 2014, Alexander et al. 2015), habitat use and preference and species richness (Rovero et al. 2014, Srivastava and Kumar 2018), assessing occupancy (Bhattacharya et al. 2012), conforming presence and secretive behaviour and species richness of arboreal mammals (Olson et al. 2012, Di Cerbo and Biancardi 2013, Whitworth et al. 2016, Bowler et al. 2017) and also for conducting general inventory of mammalian assemblage in an area (de Luna et al. 2017, Hidalgo-Mihart et al. 2017).

Camera trapping also has benefits over the other methods of monitoring wildlife. In a comparative evaluation of camera trapping, line transect census and track surveys for a rapid assessment of mammals for assessing their conservation status by Silveira et al. (2003) concluded the approach to be very effective. Camera trapping was also recommended as a cost-efficient way of surveying wildlife (Rovero and Marshall 2009, De Bondi et al. 2010). The development of the infrared flash over white flash made the camera traps less disturbing to wildlife species but the noise emitted by some infrared cameras was also detectable by wild species (Rovero et al. 2013, Meek et al. 2014) and could impact on the behaviour of passing wild animals. Previously, cameras were bulky and time-consuming to install but due to the advancement in technology they are produced relatively small, handy, water-sealed, and all the required systems are integrated into a weather-sealed single plastic case (Swann et al. 2004).

1.7 Thesis structure

The chapters of this thesis have been arranged as follows:

Chapter 1: This chapter provides brief background information about the past study of wild mammals of Nepal, and eastern Nepal in particular. An introduction to the study area and the necessities of the mammalian survey in eastern Nepal are also highlighted here.

Chapter 2: This chapter provides a brief account of the known mammalian diversity of Nepal, and eastern Nepal in particular. A detailed literature review of red panda as a target species and use of camera trapping in monitoring red panda, and other species, especially those in Nepal and the Himalayas, is provided.

Chapter 3: in this chapter, I investigate the diversity, abundance, and terrestrial activity patterns of medium and large wild mammals of eastern Nepal.

Chapter 4: In this chapter, I investigate whether the placement of camera traps, either on the ground or in the canopy, detects the highest number of the target species, the red panda.

Chapter 5: In this chapter, I emphasise the value of camera traps with details on the first photographic record of the marbled cat *Pardofelis marmorata* in Nepal along with its historical records in Nepal. This chapter has been published in the journal Nature Conservation.

Chapter 6: Finally, in this chapter, I summarise the research and where future research may go.

Chapter 2

Literature Review

2.1 Mammalian survey in Nepal

The history of mammal surveys in Nepal dates the back to early 1820s. Brian Houghton Hodgson was a self-taught naturalist, keen mammologist and audacious explorer of the early 19th Century. He laid a foundation for the natural history of the Indian subcontinent mammals, including Nepal, (between 1823 to 1843) by documenting pioneering knowledge on their natural history (Hinton and Fry 1923). He was appointed as an Assistant Resident for Nepal at the age of nineteen, and he had a precocious interest on documenting knowledge on wild mammals and birds (Datta and Inskip 2004), Hodgson became a leading authority on the natural history of the Himalayas (Arnold 2004). Unfortunately, during his stays in Darjeeling as a freelance scholar in 1845-1858, Hodgson was not able to travel to eastern Nepal due to his ill health. Sir Joseph Dalton Hooker, the first European naturalist known to collect plants in the Himalayas, travelled the Kangchenjunga area in eastern Nepal (Desmond and Prance 1999) and provided topographical information to Hodgson, which was new and first-hand (Arnold 2004). Sir Hooker also likely collected information on mammals from the area to share with his friend in Darjeeling as he was a long-time intellectual companion and house guest of Hodgson (Arnold 2004).

Besides travelling to the KCA, he also travelled to a part of this study area; the southeast of Ilam (Tongloo and Jamuna), and returned through the north of Panchthar and southeast of Taplejung to Sikkim after finishing his botanizing expedition for two months in eastern Nepal. His account of that expedition, the Himalayan Journal has some information about the wildlife they sighted and hunted (see mammal of eastern Nepal in chapter 1) but no information about the collection made by Hodgson's shooter. Datta and Inskipp (2004) mentioned that when Hodgson arrived in Nepal in 1820 the knowledge on fauna was scarce and soon, he started to make discoveries.

Before Hodgson, only three Europeans (Col. W. J. Kirkpatrick, Francis Buchanan Hamilton, and Major General Hardwicke) had made direct observations on the Nepali fauna, but Hodgson's work was intensive compared to their work (Datta and Inskipp 2004). The third observer, Hardwicke made a remarkable observational account on the red panda *Ailurus fulgens* (Hardwicke 1826). Hodgson was a very productive writer accumulating 146 zoological papers between 1829 and 1858. Among them, the majority of the papers (82) were on mammals, and the rest (64) were on birds (Datta and Inskip 2004).

Hodgson's first published research in Nepal was on the description of the gestation and birth of a Greater One-horned rhinoceros *Rhinoceros unicornis* in Nepal (Hodgson 1825).

The Tibetan antelope was named after Hodgson by Dr Clarke Abel as *Antelope hodgsonii,* now known as *Pantholops hodgsonii.* In total Hodgson discovered twenty-two new species of mammals from Nepal and Tibet (Datta 2004). Some of them are blue sheep *Pseudios nayaur,* yellow-bellied weasel *Mustela kathiah,* Hodgson's bat *Myotis formosus,* great roundleaf bat *Hipposideros armige,* black-lipped pika *Ochotona curzoniae,* Tibetan fox *Vulpes ferrilata*, pygmy hog *Sus salvania*, and the takin *Budorcas taxicolor.* He was able to collect a specimen of 114 species of mammals from Nepal, of which 40 species were described for the first time (Gray 1846, 1863). Hodgson's contribution to Himalayan vertebrate zoology was immense. Besides describing new species, he also made observations of the animals and their internal anatomy. He was the first to publish a checklist of Nepal's mammals (Datta 2004). His corrected classified catalogue of mammals of Nepal listed 99 species of mammals from Nepal (Hodgson 1841).

An annotated checklist of 119 species in 81 genera of mammals was presented by Hinton and Fry (1923). Their checklist was based on the collection made by Kennion and Baptista between August 1920 and March 1921. They also examined the manuscripts and drawings of B. H. Hodgson. The collections were mostly from the Kathmandu valley and its surroundings. Some of them are also from an area near to Koshi River in eastern Nepal. Their checklist was again supplemented by Fry (1925). Mitchell (1975) accumulated a checklist of 145 species records of mammals from Nepal based on previous collection records. Later, Mitchell and Punzo (1976) reported *Ovis ammon* and White-spotted Chevrotain *Tragulus meminna* for the first time from Nepal. They were reported from Mugu and Nawalparasi district of Nepal respectively. Suwal and Verheugt (1995) reported 181 species from 39 families in 12 orders of mammals from Nepal. Later, a review article by Majupuria and Majupuria (2006) presented a checklist of 187 species where they also included a mythical animal, Yeti.

The latest checklist of mammal species of Nepal consists of 192 species from 37 families in 12 orders (Thapa 2014). This checklist removed the previously listed 16 species by Baral and Shah (2008) and Jnawali et al. (2011) presenting the lack of reliable proof of occurrence of the mammal species in Nepal.

2.2 Ecology of red panda

2.2.1 Red panda, its global distribution, and legal status in range countires

Red pandas are endemic to the Eastern Himalayas, ranging from western Nepal, into north-east India (West Bengal, Sikkim, and Arunachal Pradesh), Bhutan, and northern Myanmar to Sichuan province of China (Wei et al. 1999a, Choudhury 2001, Dorji et al. 2012). The species is listed in the CITES Appendix I (CITES 1995) and legal protection is provided throughout its range (Dorji et al. 2012). In Nepal's Red

List it has been listed as Endangered under criterion C2a(i) (Jnawali et al. 2011) and is also listed in a protected priority list of the National Parks and Wildlife Conservation Act 2029 (1973) (GoN 1973). Red panda in the area of Jamuna and Mabu villages of Ilam district (also part of study area of this thesis) was placed in a critically endangered classification due to the extreme, market motivated utilisation of the habitat and predation by local dogs (Williams 2004, Rijal 2008). Identified red panda habitat is highest in Nepal (17,400 km^2), followed by China (8,100 km^2), India (3,200 km^2), Myanmar (2,900 km^2), and Bhutan (600 km^2) (Kandel et al. 2015). A recent study showed that the largest estimated habitat for red panda falls in China (82,653 km^2), followed by Nepal (20,150 km^2) and Myanmar (12,623 km^2) (Thapa et al. 2018). The differences in the identified global habitat of the red panda are due to the differences in the habitat distribution prediction models that the researchers used.

Among the two subspecies of the red panda, the Nepalese red panda *Ailurus fulgens fulgens* has a broader range and *Ailurus fulgens styani* is restricted to Sichuan and Yunnan Provinces of China, northern Burma, and Tibet (Fisher 2011, Glatston et al. 2015). The former has the smaller overall size based on the cranial features and prominent white face mask according to Thomas (1902) as cited in Fisher (2011). The Brahmaputra River creates deep gorges in the Himalayan Mountain system and is considered a geographical and ecological barrier between the two subspecies (Roberts and Gittleman 1984). The teeth and tail of the *A. f. styani* are relatively larger and longer respectively than the *Ailurus fulgens fulgens* (Groves 2011). In Nepal, red pandas are reported from 24 districts with their majority of habitat falling outside of the protected area network (Bista et al. 2016).

2.2.2 Habitat requirement

Red pandas are arboreal and solitary animals (Hodgson 1847, Reid et al. 1991, Yonzon and Hunter Jr 1991). Their anatomical characteristics (with a long tail) and physiology indicate an arboreal evolution with subsequent adaptation divergence into terrestrial foraging to exploit and maximise the use of the overabundant local food resource of bamboo (Reid et al. 1991).

Red panda is mostly found in broadleaved deciduous and coniferous forest of the temperate region and sub-tropical areas, with the exception of Meghalaya in India, where the species is also found in tropical forest (Choudhury 2001). Its habitat ranges up to sub-alpine forest (Johnson et al. 1988, Pradhan et al. 2001a) and alpine forest (Dorjee et al. 2014) that have an abundance of bamboo. Choudhury (2001) stated that the distribution of red panda above the tree lines should be infrequent because of the arboreal nature of the animal. A Population and Habitat Viability Assessment (PHVA) workshop held in September 2010 estimated the meta-population of the species to be roughly between 237 and 1,060 individuals (Jnawali et al. 2012). This estimate of the red panda population used expert opinion, data from published and unpublished studies in the simulation software program *Vortex.* The red panda international studbook data from the European and North American subpopulations of *Ailurus fulgens* was used for calculating life table parameters. The preferred altitudinal distribution range of red panda has been observed as very narrow in different studies; 2,800-3,900 m in Langtang National Park in Central Nepal (Yonzon and Hunter Jr 1991), 3,251-3,500 m in Central Nepal (Bista et al. 2017), 2,800-3,000 m in Ilam district of eastern Nepal, using the range of 2,200-3,000 m (Williams 2004), 3,000-3,300 m in Rolpa, mid-west Nepal (Lama 2013), and 2,800-3,600 m in SNP in India (Pradhan et al. 2001a), which is adjacent to the Ilam district. Despite the narrow altitudinal range, there are a range of microhabitat requirements: a dense understory of bamboo, abundant water sources, fallen logs and stumps, rhododendrons, high tree density, high canopy cover, plenty of fruiting and evergreen trees (Reid et al. 1991, Yonzon and Hunter Jr 1991, Wei et al. 1999a, Pradhan et al. 2001a, Dorji et al. 2011). Red panda prefer the southern and eastern slopes in comparison to the northern and western slopes (Dorji et al. 2011). The lowest reported sighting of red panda are at 2,000 m in Jogmai, Ilam, Nepal (Sonam Lama, pers. obs., 2009), 2,210 m in Ilam, Nepal (Bista et al. 2017), 2,400 m at SNP, India (Pradhan et al. 2001a) and 2210 m in Bhutan (Dorji et al. 2011).

2.2.3 Birthing and sexual dimorphism

The weight of an adult red panda ranges from 3.7 – 6.2 kg (Roberts and Gittleman 1984). Their mating period occurs between late January to late March (Yonzon 1989). The birthing season of the wild red panda is at the end of June or early July and the first week of November is reported as weaning time for juveniles (Reid et al. 1991), which is almost the start of winter (Roberts 1975).

The sex of red pandas cannot be distinguished by visual observation as they lack conspicuous sexual dimorphism (Roberts and Gittleman 1984). They can only be distinguished as a female if they are accompanied by a cub (Pradhan 1999) and has been observed in the SNP, India (Pradhan et al. 2001a). Shrestha et al. (2015) have identified that the individual red panda has a significant difference in their face-marks, and tail rings which could effectively contribute to the identification of individual animals. They are solitary in behaviour in the wild except during the mating period (Johnson et al. 1988, Yonzon and Hunter Jr 1991).

2.2.4 Home range and population density

Red panda show mutual tolerance to each other (Reid et al. 1991). Both sexes may have territories but there is no evidence of territorial conflict behaviour (Jnawali et al. 2012). The home range for a female red panda in China over 10 months and a male over 9 months were respectively 0.94 km^2 and 1.11 km^2 in China (Reid et al. 1991). In another study, the home range for a female red panda in China was 3.4 km^2 over a 9 month period (Johnson et al. 1988). The home ranges of adult red pandas in Nepal are considerably larger (males: 1.7-9.6 km^2; females: 1-1.5 km^2) than from China (Yonzon and Hunter Jr 1991). Their differences in home range might be caused by the differences in season and the availability of fruit trees (Reid et al. 1991) or might be due to being different subspecies. The population density of red panda varied in different studies in Nepal and India, i.e. 1 animal/4.4 km^2 in Nepal (Yonzon and Hunter Jr 1991), 1 animal/2-3 km^2 in China (Reid et al. 1991), 1 animal/1.38 km^2 (Williams 2004) in Ilam, Nepal, and 1 animal/1.67 km^2 in SNP, India (Pradhan et al. 2001a).

The daily activity patterns of two red pandas studied by radio telemetry in China were similar, being most active in the daytime, and least active in the night-time with the medium level of activeness around midday. They used small areas in late winter (February and March) in contrast to the big area used in April. The movement level of the panda was noticeably higher in summer, possibly caused by foraging for arboreal fruits over long distances and by the demand of high caloric intake by the lactating mother. The pair shared their home range extensively, overlapping by around three-quarters. Both red pandas were least active in the month of highest snowfall (March) and their movement increased conspicuously in April (Reid et al. 1991).

The first extensive study of red panda in the wild was done in China which provided the first data on the movement and activity patterns of red panda in the wild (Johnson et al. 1988). Subsequent studies by (Yonzon and Hunter Jr 1991), Reid et al. (1991), (Pradhan et al. 2001a) also contributed significantly in the knowledge of various aspects of red panda ecology in the wild but there are still many areas of ecology, population, and human dimensions to be researched.

2.2.5 Food habits and defecation pattern

Red pandas have a more diversified diet than giant pandas as they extend their bamboo diet to feed on seasonal wild berries and fruits. The red panda is small and efficient at climbing limbs of fruit-bearing trees and shrubs (Reid et al. 1991). The red pandas in Nepal mainly feed on leaves of bamboo, accounting for 68.4% of their intake (Yonzon and Hunter Jr 1991). Examining 332 fecal pellets of red panda in China, they were found to contain 99.1% bamboo in all seasons (Johnson et al. 1988). In SNP two species of bamboo were found to be consumed; malingo (*Yushania maling)* and rato nigalo (*Arundinaria aristata)* (Pradhan et al. 2001b) whereas the leaves of bamboo *Bambusa fagiana* was the major food item found in China (Reid et al. 1991). A high level of dietary overlap with giant panda was observed in Chinese habitats (Johnson et al. 1988).

Red pandas cope with the restriction of their low nutrient diet by swift ingestion and continual digestion (Gittleman 1988), which make them active most of the time, 45-49% of the day in China (Reid et al. 1991) and 56% in Nepal (Yonzon and Hunter Jr 1991) with several rest periods in between. The defecation of red pandas occurs in groups which constitutes single or multiple (repeated) defecations (Reid et al. 1991, Yonzon and Hunter Jr 1991). Water sources are a major component of the red panda habitat because the distance to the nearest water source from the locus-specific latrines was less than

100 m for 90% of them in Langtang National Park (Yonzon and Hunter Jr 1991), 79% in SNP, India, more than 70% in Bhutan (Dorji et al. 2012), 97.62% (Kandel 2009), and 80.33% (Rijal 2008) in Ilam, eastern Nepal.

The most preferred latrine site of red panda in all studies have been found to be up trees, followed by the forest floor, rocks and fallen stumps and logs (Pradhan et al. 2001a, Williams 2004, Rijal 2008, Kandel 2009, Lama 2013, Bista et al. 2017). The use of the trees as defecation sites ranges from 44.5% to 91% within populations. The use of the forest floor for defecation was next highest. The use of the defecation sites also differed with the seasons. The forest floor was used more in winter and the monsoon in SNP, India. The encounter rate of pellet and pellet groups were high in the forest floor (45.9%) followed by tree (29%) and rocks (18.9%) in winter but in other seasons (pre-monsoon, monsoon and post-monsoon), the use of tree was higher (Pradhan et al. 2001a). Contrastingly red pandas used trees (91.4%) mostly for defecation during winter and also in spring in Ilam (Williams 2004).

2.2.6 Use of tree by red panda

The tree species *Rhododendron arboretum, Lithocarpus pachyphylla, Schefflera rhododendrifolia, Abies densa, Abies spectabilis, Acer campbelli, Sorbus cuspidata, Magnolia campbelli, Betula utilis, Quercus pachyphylla, Quercus lamellosa, Hymenodictyon excelsum, Litsea* sp.*, Vitex heterophylla, Rhododendron falconerii,* and *Michelia dolsopa* were used by the red pandas in Ilam, Nepal and SNP, India (Pradhan et al. 2001a, Williams 2004, Rijal 2008, Kandel 2009). All of the tree species *(A. densa, B. utilis, Ilex* sp.*, M. campbellii, Osmanthis sauvis, Q. pachyphylla, Rhododendron* sp., *and S. impressa)* that had direct sightings of red panda (Pradhan et al. 2001a) were evergreen except for *M. campbellii.* Bamboo is also an important component of the red panda habitat (Bista et al. 2017).

The high use of trees for their daily activities is also supported by the different direct sighting records (Pradhan et al. 2001a, Williams 2004). Out of 32 direct sightings, 81.25% of the sightings were on the trees, the rest being on the ground in broad-leaf deciduous forest followed by subalpine and oak forest in SNP, India (Pradhan et al. 2001a). Williams (2004) observed 60% of the sightings in Ilam, Nepal were in the trees followed by ground.

The maximum encounter height of the red panda pellet in the tree trunk is quite similar in Ilam, east Nepal and Rolpa, mid-west Nepal with an average height of 4.5 m and 4.29 m respectively with the range pf 2.5-14 m in Ilam, east Nepal and 1.7-7.7 m in Rolpa, west Nepal (Rijal 2008, Lama 2013).

2.2.7 Natural predators of red panda

A natural enemy of the red panda is the leopard *Panthera pardus* (Yonzon and Hunter Jr 1991). A leopard in Langtang National Park predated two adults and one cub. The large felid or canid predators cannot access the cavity in fully grown or overgrown coniferous trees, which provide good maternity dens, although less common predators, like yellow-throated marten *Martes flavigula*, possibly enter the dens (Reid et al. 1991). The maximum cover of bamboo, bamboo height and forest canopy cover appear vital factors in habitat sites utilised by red panda Pradhan et al. (2001a) and the impenetrable bamboo cover could also provide safe cover from a predator whose hunts rely on vision (Reid et al. 1991). Unfortunately, more than 50% of the deaths of pandas in Langtang were related to hunmans (Yonzon and Hunter Jr 1991).

2.2.8 Significance of eastern Nepal for red panda and threats

The Kangchenjunga Ilam Complex in eastern Nepal is an important red panda habitat as it is home to the largest known population of red pandas (Jnawali et al. 2012). Habitat loss and degradation caused by various anthropogenic activities, poor enforcement of the law, unintentional poaching, trans-border affairs, lack of awareness and research, haphazard developmental activities and natural consequences like mass die-off of bamboo as the threats to the animals in this sub-population. Intentional poaching of a red panda with use of snares has also emerged in recent years as a threatening challenge in the Kangchenjunga complex (Anonymous 2016). The Singhalila range of India and Nepal in the Kangchenjunga Complex has been a major source of a red panda to the western zoos, where around 200 red pandas were traded from Nepali region in the 1960s (Bahuguna et al. 1998). The majority of subpopulations of red panda in Nepal are very small, around 20-50 animals, with a high probability of extinction even in the absence of human-induced threats (Jnawali et al. 2012). The collection of the data on size, location and dispersal rate including numbers and distribution, size of the home range and the necessity of the resources are among their key recommendations to be considered.

2.2.9 Research gaps for red panda

Many studies have been done using transect surveys (Williams 2003, 2004, Kandel 2009, Williams et al. 2011, Lama 2013, Bista et al. 2017) to detect the presence of red pandas, distribution, habitat use, and a study of their diets (Wei et al. 1999b, Pradhan et al. 2001b, Wei et al. 2009, Zhang et al. 2009, Thapa 2010, Panthi et al. 2012, Sharma et al. 2014). The species is hard to detect and observe in the dense bamboo forest. "…, if you are very lucky, you might see a little red panda, foxy brown with a furred black-ringed tail and a grizzled head, ….." (Attenborough 1984). Radio telemetry studies of the red panda by Johnson et al. (1988), Reid et al. (1991), and Yonzon and Hunter Jr (1991) have unveiled many ecological and biological aspects of red pandas but their conclusions on-time budgets and activity patterns greatly varied between the studies. A nearly two-century-old report said the red pandas appear to be active at dusk, dawn, night (Hodgson 1847). A sub-adult female studied for 9-months in Wolong Reserve was found to be crepuscular and nocturnal too (Johnson et al. 1988). In another study for both male and female panda, in the same reserve, reported higher activity level in daytime than in night, and a medium level of crepuscular activity (Reid et al. 1991). Similarly, in Fengtongzhai Reserve, China the result of six red pandas showed them to be more active at daytime than at night (Wei and Zejun 2011).

According to Wei and Zejun (2011), research effort on ecological studies of wild red pandas are geographically biased with most of the information from the Chinese red panda, *A. f. styani*. They recommended greater efforts for the study of *A. f. fulgens,* the Nepalese red panda with the use of modern biological techniques, like infrared cameras, GIS and molecular markers. Williams et al. (2011) also suggested an in-depth scientific camera trapping for red pandas and development of standard techniques of camera trapping for the species. A systematic, long-term and standardised camera trapping for red panda would help to unveil many biological and ecological aspects of this cryptic and charismatic species. Studies on population aspects, such as population size, density, and dispersal patterns, have been recommended by Thapa et al. (2018).

Johnsingh and Nameer (2012) also urged further research on the habits and biology of mammalian species, which are elusive and geographically restricted because of the possibility of the disappearance of the species before they are recorded from an area. On a global scale, Myanmar lacks information on red panda (Thapa et al. 2018).

2.3 Camera trapping to study wildlife in the Nepal Himalaya

The pioneering use of the flash camera traps in Asia was done by F. W. Champion (Champion 1928) and his classic accounts inspired conservation biologists. It was the early 1990s when the biologists started to utilise camera trapping for estimating tiger abundance in India (Karanth 1995). The first camera trapping study in Nepal was done for tigers in Chitwan National Park. Camera trapping has been used for long-term monitoring of populations of tigers in Chitwan National Park between since 1995 to 2015 (Barlow et al. 2009), despite camera trapping monitoring not being listed in the Tiger Conservation Action plan over that time (DNPWC 1999). Camera trapping methods were used for monitoring the tiger numbers, abundance, the reproductive status, life history and longevity of breeding resident females in Chitwan National Park (Charles et al. 2016).

In Nepal camera traps have been used for the study of wildlife from the high mountains to the lowland Terai region, and for small-to-large sized terrestrial mammals (Wegge et al. 2004, Aryal and Yadav 2010, Dhakal et al. 2014, Thapa et al. 2014, Karki et al. 2015, Lama et al. 2017). The camera trap studies in the Nepal Himalaya were able to detect four new mammalian species for the country, the rusty-spotted cat *Prionailurus rubiginosus* (Lamichhane et al. 2016); the Pallas's cat *Otocolobus manul* (Shrestha et al. 2014); the ruddy mongoose *Herpestes smithii* (Subba et al. 2014); and the steppe polecat *Mustela eversmanii* (Chetri et al. 2014). The first photo record of spotted linsang *Prionodon pardicolor* (Ghimirey et al. 2017); snow leopard *Panthera* uncia (WWF 2011); red panda *Ailurus fulgens* (Williams et al. 2011); Asiatic golden cat *Catopuma temminckii* (Ghimirey and Pal 2009) for Nepal and a globally highest altitude record of a leopard cat *Prionailurus bengalensis* in KCA of Nepal (Thapa et al. 2013). Long term camera trapping monitoring has been employed in KCA between 2011 and 2015, which recorded the presence of dholes after an absence of 4 years (Subba et al. 2017). Since 2010, the use of camera traps in studying wild animals in Nepal has been increasing. They are mostly being used in studying mega-carnivores to understand their population dynamics and ecological relationships. Camera trapping publications from Nepal from 2004 to 2018 were mostly on big cats (71%), tiger, snow leopard and leopard, mostly concerning tigers (59%). Most of the studies (82%) were done after the year 2010, almost all inside protected areas (94%) and only 18% of the study were on small carnivores (data assessed on 30 October 2018). Only one pilot camera trapping study on red panda, mainly to get some images from the wild, has been done with very small efforts (Williams et al. 2011).

A more intensive, dedicated and coordinated camera trapping survey (Sangay et al. 2014) of wildlife in the national and regional level would bring much information on the aspect of red panda ecology. A remarkable camera trapping project in the transboundary protected areas of the Terai Arc Landscape (TAL) in India and Nepal was also done. It resulted in more than 38,000 trap days covering >9,000 km^2 of tiger habitat to monitor movements of the tiger population in corridors and population growth rates for many years (Thapa et al. 2017). The study showed movements of individually identified tigers between the protected TAL areas of Nepal and India. In Nepal, camera trapping studies have mostly focused on the Terai region for studying tiger and sympatric felid species, such as leopards (Thapa et al. 2014, Karki et al. 2015, Thapa and Kelly 2017, Thapa et al. 2017, Lamichhane et al. 2018). Recently a large number of camera traps were used in the TAL area of Nepal to survey tiger numbers (WWF 2018). The survey with camera trapping efforts of 27,829 camera days resulted in 235 tigers being recorded, adding 114 more tigers to the baseline 2009.

Although the tiger remains the main focus of the camera trapping surveys in Nepal’s Terai region, they are also identified as an indispensable tool for surveying wildlife throughout Nepal. This has led to the documentation of many new, rare, and cryptic wildlife of Nepal. Camera trapping surveys focused on medium and large felids, like tiger, leopard, Asian golden cat, and clouded leopards, are accumulating crucial knowledge on other smaller felids (Ghimirey and Pal 2009, Thapa et al. 2013, Lamichhane et al. 2016).

Despite the wider application possibility, the use of camera traps in Nepal is only limited to the study of medium and large terrestrial mammals. Nepal is also home to the endangered and arboreal mammals, like red panda, and many other neglected, poorly known and data deficient small mammals, like flying squirrels (Sciurinae), squirrels (Sciuridae), shrews (Soricidae) and small rodents (Spalacidae, Cricetidae and Muridae). The use of the camera trapping technique to study these species could result in crucial knowledge of species identification, ecology, distribution, and association with other wildlife. A standardised camera trapping protocol which can generate more images effectively is necessary. If tested and designed with field tests, the use of camera traps in an arboreal setting could replace conventional survey methods for studying elusive and charismatic species, providing an option for developing a new monitoring technique (Mills et al. 2016, Whitworth et al. 2016). Thus, a standardised camera trapping survey protocol is necessary for Nepal. Comparatively, for long-term research and monitoring of wildlife, the camera trapping survey are less labour intensive technique and rewarding regarding cost (Whitworth et al. 2016). The standardised camera trapping protocol should also facilitate a national database of all the camera trap survey data which enables sharing of the data among the researchers and contribute to research, education, conservation, and management of wildlife species.

2.4 Arboreal camera trapping

The wildlife species from the orders of Primates, Carnivora, Hyracoidea, and Pholidota are arboreal mammals. They spend most of their time moving, feeding, breeding, and socialising in trees, as well as spending a significant amount of time moving and feeding on the grounds (Reed 1998). They have important roles in sustaining forest ecosystems (Krisanti et al. 2017).

Initially, camera traps were manufactured and used for ground research work. In forested habitats, most biodiversity inhabits the tree canopies (Wearn and Kapfer 2017). This has compelled biologists to place camera traps in trees to capture arboreal mammal species which may be cryptic, shy, elusive, and endangered in nature. The application of cameras to study arboreal species is limited, even though they are effective (Gregory et al. 2014). Recently this non-invasive (Gregory et al. 2014) and effective tool have been used for detecting secretive primates (Olson et al. 2012) and other nocturnal and cryptic species (Whitworth et al. 2016). Cameras are also being used for studies of elusive and tiny arboreal mammals, such as the hazel dormouse *Muscardinus avellanarius*, a rodent of only 15-30 g (Arkive 2017) in the United Kingdom (Mills et al. 2016), small arboreal and nocturnal species (Voss 2015), such as the streaked dwarf porcupine *Coendou ichillus* in Peru (Gregory et al. 2015), and the monitoring of small arboreal mammals in Italy (Di Cerbo and Biancardi 2013). Camera traps were also successful for detecting the first presence of the grey squirrel *Sciurus carolinensi*s, which is invasive in the habitat of indigenous red squirrels, *Sciurus vulgaris* to medium-sized arboreal mammals like

Kinkajou *Potos flavus* in Costa Rica (Schipper 2007), greater bamboo lemur, *Prolemur simus*, in Madagascar (Olson et al. 2012), and to study and monitor the frugivorous species assemblage in Guatemala (Rivas-Romero and Soto-Shoender 2015) and for inventorying elusive rainforest mammals to examine the effectiveness of arboreal camera trapping over other ground-based classical survey methodologies, like transects and incidental observations in Peru (Whitworth et al. 2016). Most of the arboreal camera trapping studies have been done in the tropical rainforest area of Central and South American countries which are reservoirs of the world's biodiversity.

Olson et al. (2012) have successfully implemented arboreal camera trapping to detect the critically endangered greater bamboo lemur, placing cameras in different settings in sub-canopy level with the help of local knowledge. Gregory et al. (2014) put the camera traps at a mean height of 26.8 m to investigate the use of the natural crossings, like tree branches and detected 20 mammal species. Among them, 16 species were not detected by ground-based camera traps. The camera trap experiment by Mills et al. (2016) successfully demonstrated the success of detecting the presence of small arboreal mammals in the sphere of existing survey techniques providing researchers greater choice and flexibility based on their requirement, interest and financial situation. Their experiment has encouraged researchers to test and develop new surveying methods even in the presence of many other survey methods. In a study of arboreal camera traps compared with a line transect (diurnal and nocturnal) in Peru (Whitworth et al. 2016), they detected more species with the camera trapping, detecting six species which were not detected in the transect survey. They also reported that, despite the high upfront payment, camera trapping was cost-effective and efficient (Bowler et al. 2017) at monitoring cryptic species compared with traditional ground-based survey methods. Similarly, Bowler et al. (2017) also used arboreal camera trapping extensively to measure their efficiency compared with line transects in inventorying arboreal mammals for modelling habitat occupancy. In their studies, the capture rate of the species increased moderately with the increase in the height of the camera placement.

No negative responses of animals to the cameras were seen in the canopy but the cameras placed in the canopy were highly false-triggered by non-targeted stimuli compared to ground-based cameras (Gregory et al. 2014, Bowler et al. 2017) and demanded extended processing time (Bowler et al. 2017). The misfires were highest in the study of Bowler et al. (2017) accounting for 98% of the recorded images, predominantly due to the movement of leaves near to the cameras. Gregory et al. (2014) achieved a significant reduction in the false triggering by clearing leaves within a 1.5 m periphery of each camera.

Another practical limitation of arboreal camera trapping is that specialised climbing techniques and skills are required to install and maintain the cameras (Bowler et al. 2017). Setting up the cameras in the canopy is time and labour consuming, demanding 2-10 hours per tree. For mounting the cameras in the canopy with greater flexibility to direct it towards the area of interest, a camera mount with a ball head is recommended by Gregory et al. (2014) and Bowler et al. (2017). If there is some intrusion by the wildlife on the cameras, mounting them into sturdy L-shaped brackets can be more effective (Bowler et al. 2017). As regular access to the camera traps is not practical, use of long life lithium batteries and high storage capacity flash cards are recommended (Gregory et al. 2014). Olson et al. (2012) have suggested the need for testing and refining the methodologies of camera trapping on arboreal mammals.

2.5 Camera trapping for arboreal red panda

Only one camera trapping pilot study has been undertaken for red pandas in Nepal which was in a very small area for a short duration (Williams et al. 2011). This study was conducted in 2010 with only six cameras, placed in tree canopies. Cameras were set for 24 hours but were left in the field for only a few days. This may be the only camera trapping study so far that has targeted red panda in the wild. The only objective of the study was to detect and capture images of red pandas from the wild. Williams et al. (2011) captured images of a red panda and recorded different behaviours (tree climbing, defecating, and sniffing the old latrines) in the wild. RPN has been using the camera traps to spy and detect the red panda poachers in eastern Nepal, and they have successfully identified one poacher (Anonymous 2016) who was prosecuted by Nepal Police.

Red pandas were also camera trapped in a study researching small carnivores in Sikkim, India by Khatiwara and Srivastava (2014) and Ghose et al. (2014). Their studies recorded the carnivore species in the Kyongnosla Alpine Sanctuary and BRS (adjacent to this study area) in Sikkim, respectively. They recorded red panda along with other sympatric species yellow-throated marten *Martes flavigula*, stone marten *Martes foina*, leopard cat *Prionailurus bengalensis*, Siberian weasel *Mustela sibirica*, spotted linsang *Prionodon pardicolor*, large Indian civet *Viverra zibetha*, and red fox *Vulpes vulpes* in their study areas. The occurrence of yellow-throated marten, a probable predator of red panda (Williams 2004), was common in both of the aforementioned studies in Sikkim. Khatiwara and Srivastava (2014) also reported a first photographic record of a red panda cub-carrying in the wild. The Sikkim study was targeted at all the small carnivores in the area. The studies in Sikkim and Nepal both showed that the red pandas could be detected by camera traps set in tree canopies and on the ground. Thus, a comparative study on the effectiveness of camera trap placement (ground vs tree canopies) on obtaining effective photos of the red panda is crucial for future monitoring of this species by camera trapping.

Chapter 3

Mammalian Inventory in eastern Nepal

3.1 Aim of the study

The overall aim of this camera trapping study was to document the existence of medium-and-large-sized terrestrial mammals in the human-dominated and non-protected forest areas of the lower Kangchenjunga region in eastern Nepal. This study also aimed to discover the season-wise and overall differences in activity patterns of the abundant mammals in the study area.

3.2 Objectives of the study

The specific objectives of the camera trap study were:

- To record the presence of all wild species of medium to large-sized mammals (>1 kg) detectable in the winter and spring seasons.
- To assess the distribution of the recorded wildlife species within the lower Kangchenjunga region in both seasons.
- To assess the relative abundance, along with monthly relative abundance, time-period relative abundance, and night-time relative abundance, of the species recorded in the study area.
- To assess the activity patterns (based on their movements – diurnal, nocturnal/cathemeral or arrhythmic) of the species recorded in the study area.
- To assess the alimentation types and predator/prey ratios of the recorded species.

In this study, medium-large-sized mammals are those over 1 kg of body weight as adults (Chiarello 2000, Tobler et al. 2008, Jansen et al. 2014).

The area lacks an accurate database for the occurrence of mammalian species (see 1.1 and 1.2). The results of this study will provide baseline data for local mammalian species' occurrence, diversity, composition, and activity patterns in the area, which will serve as baseline information for devising wildlife management, conservation, and research, and human-wildlife conflict mitigation programmes in the future. The results can also be combined for developing conservation action plans of the different community forest user groups of the area and encourage long-term wildlife monitoring for conservation and research.

3.3 Materials and Methods

3.3.1 Study Area

Location: According to Spate and Learmonth (1957) the eastern part of Nepal is labelled as East Himalaya. Our camera trap-based inventory of mammalian diversity was conducted in the three districts of far-eastern Nepal (Ilam, Panchthar, and Taplejung) covering an area of approximately 520 km^2. The study area (26°59'6.159" - 27°25'57.969" N and 87°51'24.084"- 88°6'34.282" E) has 16 villages, which border with India (except for Pyang and Maipokhari villages in Ilam and Lungrupa village in Panchthar). The villages range from Gorkhe in Ilam in the south, to Khewang in Taplejung in the north (Figure 3.1). The forests of Ilam, and some parts of Panchthar district, border the SNP in West Bengal, India. The majority of the forest area in the Panchthar district connects to BRS and KBR in Sikkim, India. Similarly, a small portion of the study area of Taplejung, on its northern tip, borders KBR in Sikkim. Thus, the study area is sited on a corridor between the Indian protected areas and KCA, in Nepal and this has been proposed as a conservation corridor by Chettri et al. (2007). According to the GPS-based camera trapping locations, the elevation range of the study area lies between 1,915 m and 4,355 m above sea level.

Climate: The seasons of Nepal are: i) Winter (January to March); ii) Spring (April to June); iii) Summer (July to September); and iv) Autumn (October to December) (Yonzon 1989). The monsoon starts in early June in eastern Nepal, and this is usually two weeks earlier than in Kathmandu (Jackson 1994). Monsoon rain decreases from the beginning of October and the colder days increase in frequency, with the leaves of the deciduous hardwoods starting to fall by the end of November (Williams 2003). The annual temperature ranges from -4.2° C to 25° C (Shrestha et al. 2008). Ilam receives more than 2,000 mm of annual rainfall and Panchthar and Taplejung receive fewer than 1,500 mm of annual rainfall (DHM 2017). January and February are usually cool, and snow falls at around 3,500 m and, occasionally, down to 3,000 m.

Vegetation zones and uses: The study area is represented by three Eastern Himalayan ecoregions: i) Eastern Himalayan alpine shrubs and meadows; ii) Eastern Himalayan conifer forests; and iii) Eastern Himalayan broadleaved forests (Wikramanayake et al. 2001). The forests of the study area are composed of different species depending on altitude, with *Quercus* sp. and a number of species of the Lauraceae family in the lower temperate forests (1,700-2,400 m); *Quercus* sps., *Rhododendron* sp., *Acer* sp. and *Pinus* sp. in the upper temperate forests (2,400-2,800 m); *Rhododendron* sps., *Betula* sp., and *Acer* sp. in the sub-alpine forests (around 3,000 m to the tree line); and shrubby rhododendron species, *Rhododendron anthopogon, R. nivale* and junipers in the alpine zone (between the tree line and nival zone). This classification is based primarily on altitude following Dombremez (1976), as cited in Jackson (1994). Much of the lower temperate forest has been cleared for cultivation (Jackson 1994) and has been affected by a slash and burn cultivation in the past. The lower limit of the temperate forest zone is usually determined by the upper boundary of cultivated land (Carpenter and Zomer 1996). The vegetation from 1,000 m to 3,000 m comprises the highest diversity and, at the same time, interactions of humans with the vegetation are also intense with diverse land use patterns in this region making the mountain ecosystem vulnerable (Shrestha 1989). In some of the study area, the practice of cultivation is observed in and around 2650 m. A study by Kunwar et al. (2008) reported twelve forest types in the study area. Free-ranging livestock grazing is prevalent above 2,500 m, impacting the forest area by over-grazing (Regmi 2008), and this has been listed as a major threat for biodiversity conservation (Shrestha et al. 2008).

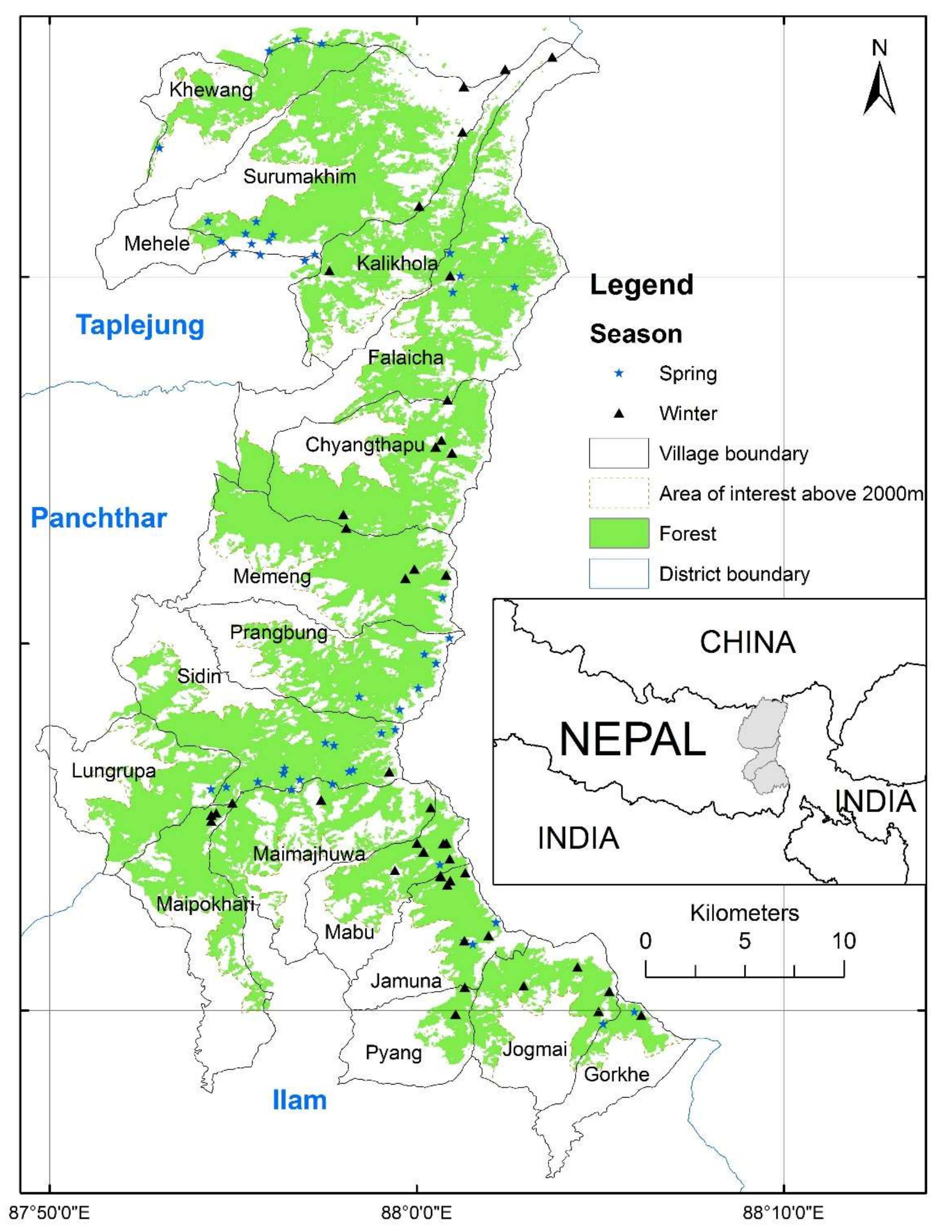


Figure 3.1: Map of study area, showing winter and spring camera trapping survey locations. Red panda dedicated camera trapping survey was conducted in southern part of the study area.

The study area has been classified into three different survey zones, i.e. temperate (2,000-3,000 m), sub-alpine (3,000-4,000 m) and alpine (>4,000 m), following Shrestha (1989). The forests of the study area are managed under different systems: government managed forests, community forests, private forests, religious forests, and leasehold forests. In parts of the study area a traditional natural resource management system, the *kipat system* also prevails (Chaudhary et al. 2015).

Mai-Valley forest, one of the Important Bird Areas (IBAs) of Nepal falls within the study area. Different types of forests in Mai-Valley are home to rare, globally threatened species of restricted range birds (Baral and Inskipp 2005). This study area has been identified as a last remaining tract of Eastern Himalayan broadleaf forest and a major habitat for the endangered red panda (Williams 2003). The Kangchenjunga-Singalila ridge in the Ilam and Panchthar districts are rich in flowering plants, with 598 species (Shrestha et al. 2008). Twenty-two of them are recorded as threatened.

The 2011 census, showed that Rai, Limbu, Gurung, Chetri, Brahmin, Tamang, Magar and Sherpa are the major ethnic groups in the study area (CBS 2011). According to the census, the total human population of the 16 villages of Ilam, Panchthar, and Taplejung districtss in the study area is 54,835, with 11,633 households. The population increases, along with a decrease in altitude, as the lower regions are suitable for cultivating agricultural crops and the weather is also mild. Seventy-three per cent of the total population in the study area are literate and 98% of the total households use fuelwood as a source of heat and cooking. Within the study area, the total absentee population is 5,113. The majority (88%) of the absentee population is male as they migrate for foreign employment.

Three religions are followed in the study area: Kirant, Hinduism and Buddhism. The Limbu and Rai ethnic groups follow the Kirant religion. Their religious norms and values are mostly influenced by, or attached to, nature. Their rituals are more focused on appeasing the natural deities and spirits (Daniggelis 1997). For them, hunting is a part of the Kirant origin myth but now the practice is in decline due to the implementation of a community forestry practice, the establishment of KCA in Taplejung and the engagement of the local community people in conservation by RPN over the last decade. I interviewed an old Rai person in Mabu village who was a fourth-generation licensed hunter in his family. The license was provided by British India in Darjeeling at that time. Darjeeling, in India, is only around 50 km away from the site. He told me that the Rai people are very agile, sporty, and nimble and adapted to hunting in the rugged terrain of the mountains and that hunting skills are passed on from father to son. He mentioned hunting red pandas (live trapping), leopard cats, pheasants and other species for zoos and personal menageries in Darjeeling. He received 90 Indian Rupee (INR) = US$ 1.29 (@US$ = INR 70) for a live red panda and INR 5 for a bird, which was a very lucrative income in the 1940s. They used to buy clothes and salt from Darjeeling with money they made from selling animals. He also mentioned that the Vedas, the religious texts, which were the foundation of Hindu theology, were first written on hides of a Himalayan serow. The practice of hunting by the local ethnic group is still prevalent in the area. The recent hunting of a Himalayan serow in Mabu village of my study area (Gurung 2018) and hunting of red panda (Anonymous 2016) corroborates that the hunting is still in practised in eastern Nepal. The current hunting practices in the villages are for the purpose of collecting meat and also for selling illegal wildlife parts, such as bear bile, skin of leopard, and scales of pangolin (pers. comm. K. Rai, April 2018).

The majority of people rely upon agriculture for their living and they practice a mixed farming system of crop production and animal husbandry together (Chaudhary et al. 2015). The large-scale cultivation of large cardamom, *Amomum subulaum,* a major component of the local economy, is common in the KL region below 2000 m (Sharma et al. 2009). In the past, the forest below 2,000 m was severely affected by subsistence agriculture similar to the Makalu-Barun area of east Nepal (Carpenter and Zomer 1996). However, protection of the forests of Nepali alder, *Alnus nepalensis,* for the cultivation of large cardamom has been observed in recent years as they provide shade, good compost from their leaves and fix nitrogen (Shrestha 1989). On the other hand, the large-scale felling of the alder forests to supply timber to saw mills is observed in areas of Ilam and Panchthar due to the availability of rough road transport to the villages. This might negatively affect the composition of the wildlife in agro-forestry habitats. Animal husbandry is another source of income for people in higher areas of the region. They rear yak, dzomu, cow, and sheep in the alpine pasture areas in summer and in temperate areas in winter. Thus, the people of the area have been adopting mountain agriculture, possessing private land and livestock holdings, agro-pastoral transhumance and sustenance agro-pastoralism, along with another type of economic enterprises (Williams 2004).

3.3.2 Time schedule

The camera trapping inventory of the medium-large-sized mammals was accomplished in two phases over two different seasons, i.e. winter (January-March 2018) and spring (April-June 2018). The first phase of the camera trapping study took place from 24 December 2017 to 22 March 2018, which is during the winter season. The second phase of the study took place from 25 March to 18 June 2018.

The winter survey was first initiated in Gorkhe village in Ilam, the southern tip of the study area, where seventeen camera traps were set up. The installation of seventeen camera traps occurred from 24 December 2017 to 2 January 2018. These camera traps were shifted to another location of Ilam between 25 January and 18 February 2018. There was a total of 31 camera trap locations in Ilam district. Similarly, nineteen camera traps were installed in the forest areas of Panchthar (15) and Taplejung (4) district for the winter survey, between 8 and 14 January 2018. Some of them were also moved locally from one place to another in winter.

During the spring survey, the numbers of camera traps were 8, 29 and 17 in the Ilam, Panchthar, and Taplejung districtss, respectively. The duration of the spring camera trapping was between 14 March and 8 May 2018 in Ilam and Panchthar. In Taplejung, it was undertaken in two phases: the first between 10 April and 1 May 2018 and the second between 16 May and 18 June 2018 for thirteen and four camera locations, respectively.

3.3.3 Camera Trapping Design for Mammalian Inventory

Training on camera trap handling:

The local knowledge of the terrain and areas of interest for wildlife species were based on the experience of the Forest Guardians (FGs) of RPN, who have been monitoring red pandas in the study area using line transects (RPN 2016b). The FGs were mobilised to install camera traps and collect the data throughout the study. Prior to that, a two-day workshop on the handling of camera traps and field data collection methods were organised by RPN in Ilam during November 2017. During the workshop, the FGs learned to set up the cameras in the field and run them for a night. Later, during the field survey, I retrained and supervised each of the FG again while setting up the camera traps. Site selection techniques were also taught to them. A camera trap setting manual and points to ponder were also prepared and distributed to each FG for future reference.

Camera trap type and their setting

In total, 63 passive infrared camera traps, 51 units of Bushnell® TROPHY® Cam HD camera trap from Bushnell Outdoor Products, USA and 12 units of Strike Force Elite camera traps (Model BTC-5HDE) from Browning®, Australia, were mobilised for the entire survey (Table 3.1). Among them, a dozen camera traps were also mobilised to study red pandas in the forests of Ilam and Panchthar districts, which also had Camlockbox Security boxes and Master Cable Locks to secure them from theft. These camera traps were set in tree canopies to monitor red pandas. The Browning camera traps were only used during the spring survey in twelve camera locations in Taplejung for 330 trap days.

Table 3.1: Setting for the Bushnell Trophy HD & Browning camera traps; these settings were followed to maintain a standard for both camera traps.

Camera	Mode	Image size	Image format	Capture number	LED control	Interval	Sensor level	NV Shutter	Camera mode
Bushnell®	Camera	20MP	Full screen	3 photos	High	03S	Auto	Auto	24 Hrs
Browning®	Still pictures	16MP	Full screen	3 photos	-	05S	-	-	24 Hrs

Camera	Time stamp	Sensor	Flash range	Night vision flash	Power supply	Trigger speed[1]	Recovery time[2]	Light source	Detection distance/ sensor range
Bushnell®	On	PIR	100 feet	Low glow	AA (8)	0.2 sec	0.6 sec	Infrared LED	100 feet
Browning®	On	PIR	120 feet	-	AA (6)	0.65 sec	1.3 sec	Infrared LED	80 feet

Both models of camera traps were set to take three consecutive photos after sensing a motion. The interval difference for a camera trap to take photographs was three seconds for the Bushnell camera traps and five seconds for the Browning camera traps.

The Bushnell 20MP Trophy Cam HD and Browning trail cameras used for this survey were equipped with an infrared flash that was triggered by a passive infrared heat and motion sensor. The infrared flash is the better option than a white flash because the white flashes are more likely to frighten and change the behaviour of the target animals although the photos produced are more easily recognisable (Glen et al. 2013). Infrared is less detectable by most mammals but the noise they make can be heard by animals (Meek et al. 2014). The date, time, weather, and location stamp were set for each of the images captured. The cameras were in the operation for 24 hours a day.

The photo quality was such that recognising individual species on both cameras could be done both day and night.

Criteria for placement of camera traps:

First, the forest areas above 2,000 m in altitude were selected by geoprocessing in ArcGIS 10.2. This was done intentionally, as in the aforementioned conditions in the vegetation zones and uses, the lower limit of the temperate forest area is usually marked by the upper boundary of the cultivated land. The focus of this study was also in and above the temperate forests of eastern Nepal. The approximate area of forest was 520 km^2 in the lower Kangchenjunga region. Uniform grid cells of 2 km x 2 km were imposed throughout the selected area of interest to ensure an even coverage of the study area. This resulted in 211 grid cells throughout the study area, of which only 60 grid cells were sampled, based on the location selected that reflected opportunistic interests, habitat type and accessibility.

The placement of the camera traps was mostly opportunistic across the grids for both seasons (winter and spring). The forest areas have been monitored by the FGs for a long period of time and these areas

[1] Trigger speed: the time elapsed between the first sensing of a motion of an object by a camera until it captures a photo of that motion.
[2] Recovery time: the amount of time taken by a camera between the first and second photographs triggered.

are well known. Sites omitted were those in private forest areas, to avoid confrontation with the local people, and difficult rocky mountain cliffs and steep mountain slopes because of inaccessibility. Within a selected grid, active trails and major areas of interest to wildlife, major passes along mountain ridges, the presence of scats and pellets, and animal footprints were chosen for the installation sites of the camera traps. The sites were also chosen based on the microhabitat traits of interest, like containing water ponds/holes, denning areas, wildlife grazed areas, cave-like areas for sheltering animals and mineral licks. The grid cells near human settlements and trails highly used by humans were also avoided to be safe from thefts and vandalism of the camera traps. But in high altitudes, many camera traps were set up along human trails because of fewer people in these areas during winter. The trails were actively used by wildlife as scats were visually sighted in these areas.

Camera traps were also opportunistically installed inside forest areas with a bamboo understory to secure greater chances for capturing species that prefer a dense and undisturbed habitat and/or are specialists in this type of habitat, like red pandas preferring to feed on bamboo. The whole study area was considered as a single block and the camera traps were moved from one site to another.

The GPS location of each camera trap's location was recorded. Other spatial data were recorded, such as aspect, vegetation/forest types, distance from the nearest settlement, distance from nearest cattle herders' station, distance from nearest forest edge, distance from nearest forest/park area over the border in India, proximity to permanent-natural water sources, and disturbance factors (felling and looping of the trees, occurrence of livestock or animal snares) of the camera placement location, etc. were also collected at the time of camera installation in the field. The total time consumed for setting up and removing of the camera traps was also noted. The location and altitude of each site were recorded using a Gramin eTrex® 10 and Rino®120 handheld GPS.

On average, camera traps were left in a location for 28 trap days. The minimum number of trap days for a camera was 14, while 78 trap days was the maximum. After the camera has been set up in the field, every 24 hours was considered as one camera trap day for this study. Over the entire survey, winter and spring, the camera traps were installed at 107 locations (39 in Ilam, 44 in Panchthar and 24 in Taplejung). Cameras were secured to available tree trunks and poles in the field, usually with a diameter at breast height of more than 15 cm (Srbek-Araujo and Chiarello 2005), which allowed a tight fit to avoid displacement by curious wildlife and livestock. A stone, typically more than one kg, was also used to secure the camera traps in alpine areas where trees were absent. The average sensor height of the camera traps installed above ground level was 32 cm to better capture medium-to-large sized mammals (Rowcliffe et al. 2008, Tobler et al. 2008, Liu et al. 2013, Rovero et al. 2014), as well as small mammals. The height of the camera traps placement ranged from 10 cm to 135 cm, based on the topography of the mountainous landforms to allow the cameras to take photos effectively.

Although false triggering by ground cameras is relatively lower than for canopy cameras (Gregory et al. 2014, Bowler et al. 2017), the vegetation and stems of bamboo were cleared over an area of c. 2.5 m wide and c. 10 m long in the probable direction of an animal detection. This was also done to reduce false triggering by the movement of the leaves of plants and bamboo stems. The fronts of the camera traps were chosen to face north or south to reduce false triggering of the cameras by the direct heat of sunlight during sunrise and sunset (Si et al. 2014).

Each camera traps and memory cards were individually coded with a unique number and the codes were noted on the field data sheet while setting up the cameras. Only one camera trap was placed in a camera station to maximise the number of stations for camera traps. Baiting was not used at stations to avoid changes in the natural behaviour of the animals (Long et al. 2012). Before leaving the cameras in the on mode, a few trial shots were tried at each camera location by taking photographs of ourselves and checking them on a point and shoot camera to determine the field of view of the camera traps. The camera traps were checked every two weeks to identify those that were no longer working due to dislocation by wildlife and livestock, battery depletion and full memory cards.

3.3.4 Distribution of camera trap locations

The camera traps in the study area were installed from 1,915 m to 4,355 m altitude above sea level.

Winter season:

After camera handling and data collection training to FGs, and following the aforementioned camera setting and criteria of placement (see 3.3.3), the cameras were left at 53 locations from 24 December 2017 to 22 March 2018 during the winter months (Figure 3.1).

Overall, in the winter season, 1,402 camera days were accumulated from 53 locations in the Ilam, Panchthar, and Taplejung districts at altitudes ranging from 2,310 m to 4,355 m (Table 3.2). During the winter, the camera traps in Taplejung, which mostly covered areas above 4,000 m, were removed after a short period to avoid coverage of the cameras by snowfalls.

Spring Season:

Overall, in the spring season (April-June), the total camera trap days accumulated 1,612 days from 54 locations in Ilam, Panchthar, and Taplejung districtss altitude, ranging from 1,915 m to 3,462 m (Figure 3.1, Table 3.2).

Table 3.2: A summary of camera trap stations, camera trap days, and elevation band utilised for camera trap distribution during winter and spring season in each district.

District	Season	Camera stations	Camera trap days	Elevation (m) band utilised for camera trap distribution
Ilam	Winter	31	1,031	2,300-3,100
Ilam	Spring	8	283	2,300-2,850
Panchthar	Winter	15	250	2,600-4,350
Panchthar	Spring	29	964	2,000-3,450
Taplejung	Winter	7	121	2,650-4,300
Taplejung	Spring	17	365	1,900-3,400
Total winter		53	1,402	
Total spring		54	1,612	
Total		**107**	**3,014**	

3.3.5 Data management

SD cards (32 GB storage capacity) were used in each camera trap. Cameras could be left for at least 30 days if the location were very remote or to avoid human disturbance to wildlife by regular visits to an area.

The images captured by the camera traps were generally retrieved from each camera after one month. The data on the memory drives used in the cameras were encrypted with the help of automatic, real-time and transparent encryption software VeraCrypt 1.21 (IDRIX 2017) to protect the data from theft or unauthorised use if the cameras were stolen in the field.

After retrieving the camera traps from the field, the memory cards were replaced before placing the camera in a new location. The collected memory cards were brought to the district headquarters for transferring to a computer. The folders of the images on the computer were given unique names according to the camera's ID. Each camera ID had detailed information about the survey area, location name, GPS location, and other environmental parameters. The data were stored in two places (computer drive and an external hard drive) for safety purposes. Finally, all camera trap data were transferred from the district headquarters via WeTransfer, a cloud-based computer file transfer service (Wetransfer 2018).

3.4 Data Analysis

3.4.1 Camera base

Camera Base 1.7 (Tobler 2007) is a Microsoft Access-based tool to store, manage and analyse camera trap survey data. It can be used in different ways depending on the need for multiple camera trap surveys in a single database. It also directly ran the capture-recapture analysis in CAPTURE and the exported data can be used in many statistical and GIS software programs. This useful tool for a biologist was developed by Mathias Tobler from San Diego Zoo Global Institute for Conservation Research. For this thesis, the most useful analysis tools from Camera Base are activity patterns and composition of species.

Each photograph taken by a camera trap also recorded the date and time of every capture, and the temperature, moon phase, and location of a camera trap (if entered), as metadata in the EXIF format. Camera Base can read these metadata, produce datasets for individual captured species from multiple camera stations and surveys, and save them for further data analysis.

Initially, the camera trap photographs were checked manually to find captured images. All the photos were then imported to Camera Base (Figure 3.2) and sorted them into different species. Only the photographs of individual medium-large-sized mammals were saved for further data analysis.

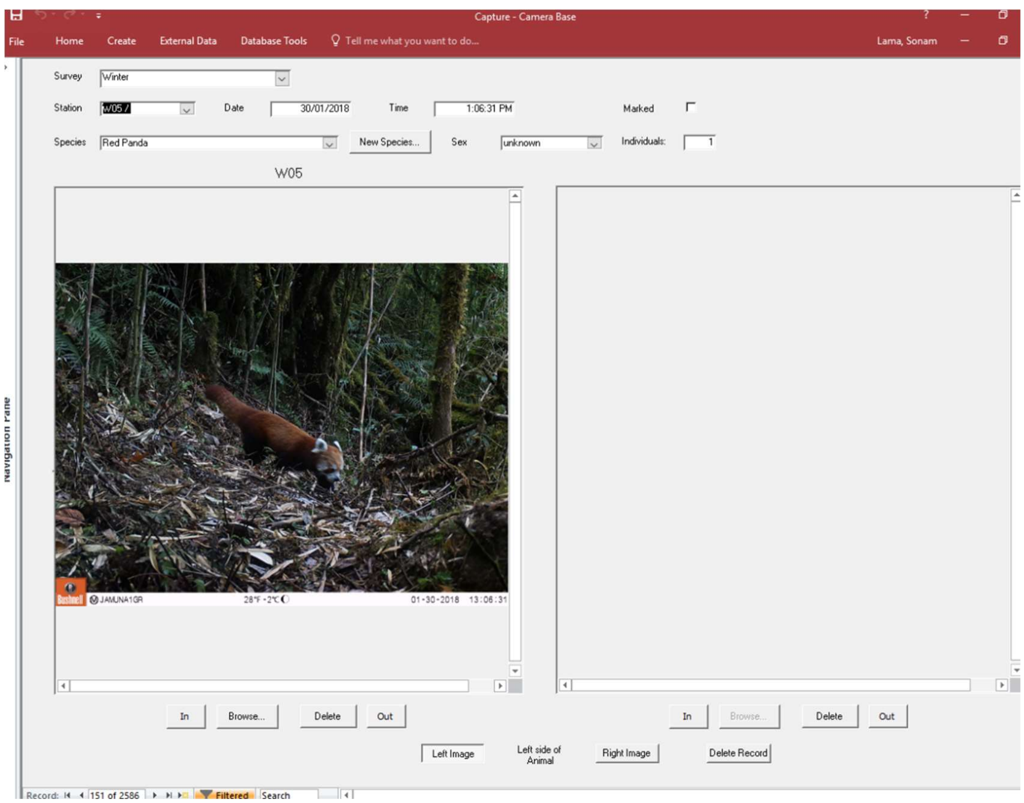


Figure 3.2: Screenshot of the user interface of Camera Base (http://www.atrium-biodiversity.org/)

3.4.2 Species identification

After entering and processing all the captured images in Camera Base, they were categorised as different individual species. Dates and times for each species were also recorded on every photograph. Very few photos were so poor in quality as to make identification impossible. To enhance the image quality of the poor images, the image viewer software, IrfanView 4.50 (Skiljan 2017), was used. The species from the photographs were identified with the help of references from Baral and Shah (2008) and Menon (2014). Additional information about the species at a global level was extracted from Johnsingh and Manjrekar (2012). Sanderson and Watson (2011) was referenced for the identification and distribution information about small cat species. For further verification experts at national and regional levels and local experts, such as FGs (citizen scientists) from local villages, were consulted. Photographs of the important wildlife species in the area were also printed and used in interviews with the local herders and past hunters to obtain more information. Dr Jim Sanderson, Dr Rinjan Shrestha, and Kashmira Kakati (Felidae), Prof. Dr Karan Bahadur Shah (Mustelidae), Will Duckworth (Mustelidae), and Sanjan Thapa (Sciuridae) provided a final verification on difficult image captures. For a check-list of the camera trapped birds in this study (Grimmett et al. 2016) were referenced. Naturalist, Mr Ramesh Chaudhary, helped on the identification of the bird species captured by the camera traps. Species-level identification of all species of flying squirrels was not possible due to the nocturnal photograph lighting.

The current global and regional conservation status for each species recorded in the study area was extracted from the IUCN Red List of Threatened Species (IUCN 2018). Similarly, the National Red List status and the protection priorities of Nepal's law were referenced from the National Red List Series (Jnawali et al. 2011) and the National Parks and Wildlife Conservation Act, 2029 (1973) (GoN 1973).

Independent records of groups, territory marking, foraging, reproductive conduct and other natural history observations were noted from the photographs.

3.4.3 Exclusion of photographs on analysis

In this study, medium-large-sized mammals were those of more than 1 kg of body weight when adult (Chiarello 2000, Tobler et al. 2008, Jansen et al. 2014). The recorded mammals of this category were only used for evaluating the effectiveness of the camera trap-based inventory of terrestrial mammals. Recorded Mustelidae (weasels), small rodents (rats, pika, bats, shrews, and squirrels), Phasianidae (pheasants and partridges) and other ground-dwelling avifauna, and all domestic livestock (cows, goats, yaks, horses, *dzomus* – a hybrid from a yak and cow) and dogs, were excluded in the analysis due to the lack of consistent, positive species identification and they were also outside of the scope of the study.

The body mass of recorded terrestrial mammals was obtained from Baral and Shah (2008) and Menon (2014).

3.4.4 Independent events

Images of the species captured entered into Camera Base were grouped into separate independent events when images of the same species were taken more than 30 minutes apart at the same camera trap station (O'Brien et al. 2003, Silver et al. 2004, Di Bitetti et al. 2006). After identification of the species in each photograph, they were classified as dependent or independent events following (O'Brien et al. 2003) in Camera Base (Tobler 2007). This was undertaken as some of the species, e.g. deer and wild boar, spent sizeable times in front of a camera if there was plenty of grass or tubers to forage in the vicinity.

3.4.5 Camera trap days

The total effort of the camera trap-based survey of terrestrial mammals was calculated in terms of camera trap days (CTDs). Camera trap days were calculated by number, starting from the day of deployment to the date of removal of a camera from a station, if the memory card was not full. None of the memory cards were full as all cards used were held 32 GB of storage. If the camera had malfunctioned, the date of the last photograph was used to calculate the CTDs. Every 24 hours spent by a camera in the field was considered as one camera trap day. The total camera trap days from the entire survey was obtained by the sum from all camera locations.

3.4.6 Capture frequency

The capture frequency of each species was obtained in terms of a number of independent events for a given species/1000 camera days. Photo capture rates were calculated following (Carbone et al. 2001).

3.4.7 Index

I) Relative abundance index (RAI)

According to the independent capture rates of recorded terrestrial mammal species, an index of relative abundance (RAI), was calculated. The RAI indicates the number of days needed to capture a photo record for a species (Carbone et al. 2001). To calculate the abundance index (RAI), the following index developed by Liu et al. (2013), was used:

RAI = $\frac{A_i}{N} x 100$ (i= 1-17) (1)

where Ai represents the total number of captures of a species by all cameras, and N equals the total number of captures for all species detected during the study period.

II) Time-period relative abundance index (TRAI)

The time-period relative abundance index (TRAI) calculates the daily activity patterns of the recorded mammals. This was applied to the mammal species that were frequently captured (>6 independent events). The time of the day imprinted on images was used to calculate a daily activity pattern for the species. Each day was divided into 12 periods of 2 h each and calculated TRAI using the following formula (2):

$$\text{TRAI} = \frac{T_{ij}}{N_i} x100 \quad (i= 1\text{-}9;\ j = 1\text{-}12) \qquad (2)$$

where, T_{ij} equals the number of captures of a species in one of 12 time-periods and N_i is the total number of captures of a species over all time-periods.

The definition of the activity patterns was followed from Lynam et al. (2013).

III) Nocturnal relative abundance index (NRAI)

The nocturnal relative abundance index (NRAI) is based on the results of RAI and TRAI. It measures the nocturnality of the eight most frequently recorded species, which has at least five independent records in each season. The time period of 18:00-6:00 was used as the night period (Azlan and Sharma 2006) and the NRAI was calculated using the following formula (3):

$$\text{NRAI} = \frac{D_i}{N_i} x100 \quad (i= 1\text{-}8) \qquad (3)$$

where, D_i refers to the total number of captures of a species during the night-period (18:00-6:00) and N_i refers to the total number of captures of this species. This time period was also chosen based on the field experience of sunsets and sunrises in the study area and sunrise and sunset reports from www.weatherspark.com (Weatherspark.com 2018).

All the analyses were accomplished with the help of Microsoft Excel™, Camera Base 1.7 (Tobler 2007) and R 3.5.1 Team (2018).

3.5 Results

3.5.1 Species list, diversity and capture frequencies

During the entire survey, camera traps were deployed at 118 different locations. However, two camera trap locations, during winter, and nine camera trap locations, during spring, were excluded for various reasons (see 3.5.5). Therefore, there were 107 camera locations in the field for recording the images of medium-large-sized mammalian species for both seasons.

Table 3.3: Mammals recorded through camera trapping-based inventory in eastern Nepal (Ilam, Panchthar, and Taplejung) during winter and spring surveys, in 2018, with their Nepali name, common name, IUCN Red List status, and Nepal Red List status.

Order/Family	Species[1]	Nepali Name[2]	Common Name	IUCN Status ver 3.1[a]	Nepal Status[3]
Carnivora					
Ailuridae	*Ailurus fulgens* (F. G. Cuiver, 1825)	*Habre, Punde Kundo*	Red panda	EN	EN
Felidae	*Panthera pardus* (Linnaeus, 1758)	*Chituwa*	Common leopard	VU	VU

	Catopuma temminckii (Vigors & Horsefield, 1827)	*Sunaulo Biralo*	Asiatic golden cat	NT	DD
	Pardofelis marmorata (Martin, 1837)	*Chirbire Biralo*	Marbled cat	NT	DD
	Prionailurus bengalensis (Kerr, 1792)	*Chari Bagh*	Leopard cat	LC	VU
Ursidae	*Ursus thibetanus* (G. [Baron] Cuvier, 1823)	*Bhalu*	Himalayan black bear	VU	EN
Canidae	*Vulpes vulpes* (Linnaeus, 1758)	*Rato Phyauro*	Red Fox	LC	DD
Mustelidae	*Martes flavigula* (Boddaert, 1758)	*Malsanpro*	Yellow-throated marten	LC	LC
	Mustela altaica (Pallas, 1811)	*Pahadi Malsanpro*	Mountain weasel	NT	DD
	Mustela sibirica (Pallas, 1773)	*Siberian malsanpro*	Siberian weasel	LC	LC
	Mustela kathiah (Hodgson, 1835)	*Pitodar malsapro*	Yellow-bellied weasel	LC	DD
Viverridae	*Paguma larvata* (C. E. H. Smith, 1827)	*Kala*	Himalayan palm civet	LC	LC
Prionodontidae	*Prionodon pardicolor* (Hodgson, 1842)	*Silu Biralo*	Spotted linsang	LC	EN
Cetartiodactyla					
Cervidae	*Muntiacus vaginalis* (Zimmermann, 1780)	*Mriga*	Northern red muntjac	LC	VU
Bovidae	*Capricornis thar* (Hodgson, 1831)	*Thar*	Himalayan serow	NT	DD
	Naemorhedus goral (Hardwicke, 1825)	*Goral*	Himalayan goral	NT	NT
Suidae	*Sus scrofa* (Linnaeus, 1758)	*Bandel*	Wild boar	LC	LC
Primates					
Cercopithecidae	*Macaca assamensis* (M'Clelland, 1840)	*Aasami Bandar*	Assam macaque	NT	VU
Rodentia					
Hystricidae	*Hystrix brachyura* (Linnaeus, 1758)	*Dumsi*	Himalayan crestless porcupine	LC	DD
Sciuridae	-	*Rajpankhi*	Flying squirrel	-	-
	Dremomys lokriah (Hodgson, 1836)	*Lokharke*	Orange-bellied Himalayan squirrel	LC	LC
Muridae	*Rattus* sp.	*Musa*	Rat	-	-
Lagomorpha					
Ochotonidae	*Ocotona* sp.		Pika	-	-

[1]Taxonomic information of the mammalian species was accessed from Integrated Taxonomic Information System (ITIS) https://www.itis.gov/ as of 5 November 2018
[2]Nepali names were accessed from Baral and Shah (2008)
[a]EN: endangered; VU: vulnerable; NT: near threatened; LC: Least concern IUCN (2018)
[3]EN: endangered; VU: vulnerable; NT: near threatened; LC: Least concern; DD: data deficit.
IUCN Status ver. 3.1 as of 5 November 2018 from IUCN (2018) https://www.iucnredlist.org/
Nepal's red list status was extracted from Jnawali et al. (2011)
- Not applicable

Overall, 3,014 trap days were accumulated (1,402 in winter and 1,612 in spring) from the 107 camera trap stations (53 in winter and 54 in spring), resulting in 93336 photographs (5,177 of wild mammals, 3,621 of birds, 11,692 of people and livestock, 65,488 ghost photos and 6,061 during camera set up) (Table 3.4). During the entire study period, the occurrence of 23 species of mammals (small-large-sized) belonging to five orders and 15 families, were recorded (see Table 3.3 for a complete list, including their national and international status). Of these, 17 were medium-large sized mammal species and they were considered for further analysis. Some noteworthy endangered species, such as red panda, *Ailurus fulgens,* common leopard, *Panthera pardus,* and Himalayan black bear, *Ursus thibetanus,* were recorded. In total 37 species of birds were recorded by the camera traps (Appendix A).

Table 3.4: Summary of the camera trapping sampling efforts during winter and spring camera trapping survey in eastern Nepal.

	Winter Season	**Spring Season**	**Total**
No. of effective stations (including excluded cameras)	53 (55)	54 (63)	107 (118)
Total efforts (camera trap days)	1,402	1,612	3,014
Total of photos of medium-large-sized mammals (Independent Events)	2,587 (220)	2,590 (305)	5,177 (525)
Total photos of red panda (Independent Events)	126 (21)	33 (7)	159 (28)
Total no of mammal species#	23	17	23
Total medium-large-sized mammal species	17	14	17
Total small-sized mammal species+	6	3	6
Total photos of small-sized mammal species+	1,052	245	1,297
Total photos of bird species+	2,190	1,431	3,621
Total photos of livestock+	2,833	7,554	10,387
Total photos of human+	73	1,232	1,305
Total photos during setting of camera traps+, -	3,544	2,517	6,061
Total ghost photos due to false triggering of camera traps+	32,769	32,719	65,488
Total photos captured	**45,048**	**48,288**	**93,336**

including small mammal species, which are not included in the analysis
+ All are excluded from the analysis
- The photo taken during setting meaning the photos taken during the installation and removal of the camera traps in the field

The total camera days during the winter survey of 2,018, resulted in 2,587 positive photographs with 220 independent records of 17 species of medium-large-sized terrestrial mammals in the study area. Similarly, during the accumulated trap days in the successive spring survey of the same year, 2,590 photographs with 305 independent events from 14 species (Table 3.4) were recorded. The entire study period accumulated 525 independent records of medium-large-sized mammals in the region.

Comparatively small camera trapping effort in the winter survey compared with the spring survey, the number of recorded species during the winter survey was higher. The species only recorded during the winter survey were marbled cats, *Pardofelis marmorata,* red foxes, *Vulpes vulpes,* and flying squirrels. *Pardofelis marmorata* is an elusive felid species with a lower capture rate throughout its range. It was captured only once during the winter survey in this study (Figure 5.2, Chapter 5). The red fox was only recorded around and above 4,000 m altitude. It was not recorded during the spring survey when all camera traps were set below 3,500 m altitude (see 3.3.4).

Of the five recorded orders, Carnivora was common, with 56.6% of the total recorded species (23 sps.) followed by Cetartiodactyla (17.4%) and Rodentia (17.4%). Similarly, family-wise, Felidae and Mustelidae were common, followed by Bovidae and Sciuridae. Of the 23 recorded mammal species, nine are of high global conservation significance according to the IUCN Red List: endangered (1); vulnerable (2); and near threatened (6), (IUCN 2018). On the basis of Nepal's National Red List, out of the 23 recorded mammal species, eight species are of national conservation significance: endangered (3); vulnerable (4); and near threatened (1), (Jnawali et al. 2011). There were seven species listed as data deficient, which meant they lacked sufficient research, and this was crucial for their management and conservation. There were two felids, two mustelidae, one canidae, one bovidae, and one logomorpha listed as data deficient on a national level (Table 3.3). The vulnerable species categorised on the National Red list, *Prionailrus bengalensis,* was the third highest recorded species, and highest recorded felid species in this study (Table 3.5). The nationally endangered spotted linsang, *Prionodon pardicolor,* was not common as it was only recorded once in each season. The photo evidence of *Pardofelis marmorata* was reported for the first time in Nepal (see chapter 5 for details). In addition, the presence of the Asiatic golden cat, *Catopuma temminckii* (Figure 3.3), and the spotted linsang, *Prionodon pardicolor* (Figure 3.4), were recorded for the first time from the Kangchenjunga Landscape in eastern Nepal. A record of a melanic Northern red muntjac, *Muntiacus vaginalis* (Figure 3.5), was also made for the first time in Nepal. The melanic deer was captured during the spring season. Similarly, a record of a melanic common leopard, *Panthera pardus* (Figure 3.6), was also new for the lower Kangchenjunga region. The Asiatic golden cat and spotted linsang were captured during the both seasons (Table 3.5).

The most highly captured species were *Muntiacus vaginalis* (n=266), *Sus scrofa* (n=61), *Prionailurus bengalensis* (n=41), *Vulpes vulpes* (n=32), and *Hystrix brachyuran* (n=30) (all are "independent" events, Table 3.5). Out of 525 independent images, the muntjacs alone comprised up to 50.7%. Among the four recorded felid species, *Pardofelis marmorata* (n=1) was least recorded and *Prionailurus bengalensis* (41) was the most common in the study area, followed by *Catopuma temminckii* (6) and *Panthera pardus* (5). A felid species, suspected to be from the region, the clouded leopard, *Neofelis nebulosa,* was not captured in this study.

Figure 3.3: The first photographic record (dated 25 January 2018) of the Asiatic golden cat *Catopuma temminckii* in the Kangchenjunga Landscape in eastern Nepal. The left photo shows its ear and marks behind forelimb and the right photo clearly shows the white colour.

Figure 3.4: The first photographic record (dated 21 February 2018) of the nationally endangered spotted linsang *Prionodon pardicolor* in the Kangchenjunga landscape in eastern Nepal. This is the second photographic record of the species from Nepal.

Figure 3.5: The first photographic record (dated 20 April 2018) of melanic Northern red muntjac in Nepal. It was recorded at an altitude of 2,285 m in the Taplejung district. The date stamp in the photograph is mistaken as the person installing the camera trap set April month (mm as 04) in the place of day (dd) and the day (12) in the place of month (mm) which made it set as 04 December 2018 which was actually should be 04/12/2018.

Seven small carnivores were recorded during the study period, with leopard cats, *Prionailurus bengalensis*, being recorded most frequently, and followed by the red panda, *Ailurus fulgens* (Table 3.5). Species that were very rarely captured (n = 1) in my study during both seasons (winter and spring) were *Ursus thibetanus,*

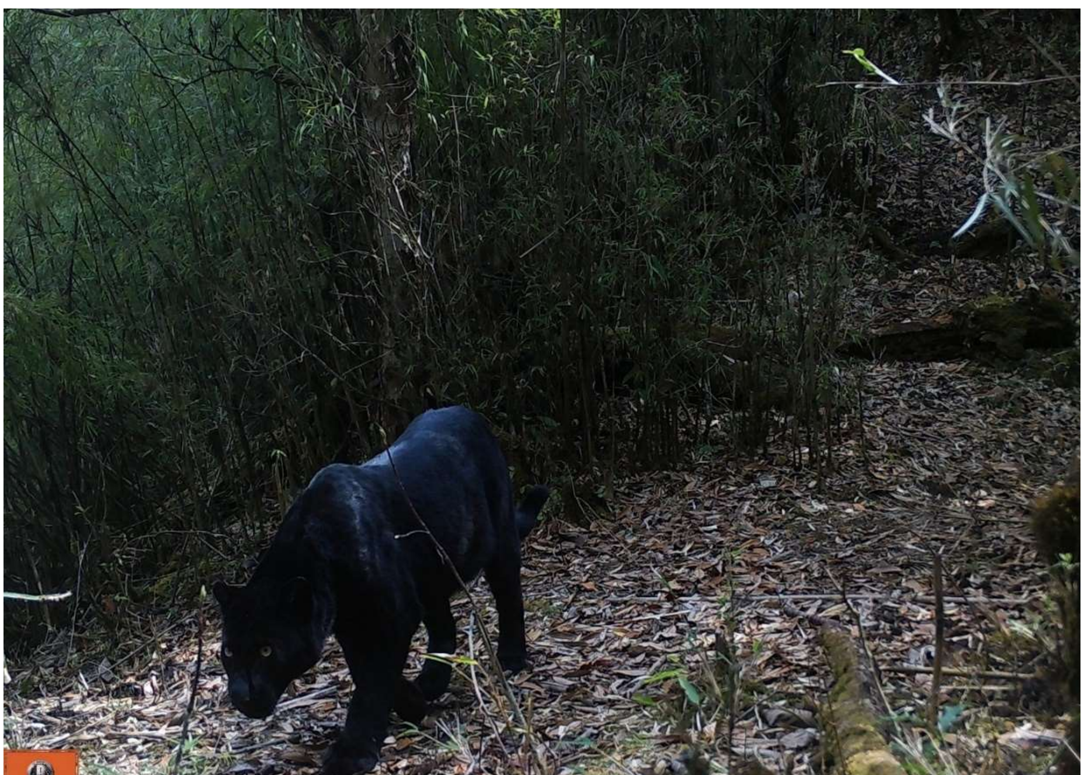


Figure 3.6: The first photographic record (dated 31 March 2018) of the melanic leopard *Panthera pardus* in the Panchthar-Ilam-Taplejung Corridor, which falls in the Kangchenjunga landscape.

Paguma larvata, and *Prionodon pardicolor*. The species that were very rarely captured during the winter season were *Panthera pardus, Pardofelis marmorata,* and *Naemorhedus goral.* Similarly, a species rarely captured during the spring season was *Catopuma temminckii.*

Species not included in the analysis of this study were the Mountain weasel, *Mustela altaica,* Siberian weasel, *Mustela sibrica,* Yellow-bellied weasel, *Mustela kathiah,* Orange-bellied Himalayan squirrel, *Dremomys lokriah,* rats, *Rattus* sp., and pika, *Ocotona* sp. They were not included because these species were all small mammals (> 1 kg) and difficult to confirm at species level, especially for the rats and pikas. Their identification was difficult due to needing nocturnal photograph lighting. They were all captured around and above 4,000 m altitude in the alpine region.

Thirty-seven different species from four orders and fifteen families of ground and forest dwelling avifauna (Appendix A) were also recorded in this study but were not included in further analysis. Among them, two species (*Tragopan satyra,* vulnerable and *Lophophorus impejanus,* near threatened) are nationally threatened birds for Nepal (Appendix C, Figure C.1.1 and C.1.2).

During the entire study period, 65,488 (70.2%) photographs were ghost photographs due to the false triggering of the camera traps by various factors.

<u>Aggregation, foraging, camera shyness, and reproductive behaviour:</u>

Among the recorded mammal species in the study area, aggregation behaviours were recorded for *Sus scrofa, Macaque assamensis, Muntiacus vaginalis, Martes flavigula, Hystrix brachyura,* and *Panthera pardus.* The *Sus scrofa* had the highest number of aggregation records (19 independent events) among them, ranging in group size from two to twelve individuals with a group of piglets from one to nine individuals. A group of adults and juveniles were also seen among *Macaca assamensis, Muntiacus vaginalis,* and *Panthera pardus. Panthera pardus* was only once recorded in a group of two individuals.

Sus scrofa and *Muntiacus vaginalis* often foraged for grasses and tubers in front of camera traps. At one event a group of three *Muntiacus vaginalis* spent 21 minutes in front of a camera while foraging on grasses. They displayed no obvious awareness of the camera traps and their surroundings, compared with the alert behaviours shown by *Prionailurus bengalensis.* Flying squirrels were always photographed during the night, as they are nocturnal, and few records of gliding movements (Appendix B, Figure B.4.3) of them were also recorded from a temperate forest with a closed canopy of *Machilus edulis, Lithocarpus pachyphylla, Quercus glauca, Symplocos theifolia, Hymenodictyon excelsum, Lyonia ovalifolia,* and thickets of bamboo in the understory.

Almost all the recorded mammals noticed the presence of the camera trap as they often looked at the camera traps. Some of them, such as *Macca assamensis, Martes flavigula, Ailurus fulgens,* and *Prionailurus benglensis,* appeared curious about the camera traps and even checked them by sniffing the camera. Despite being camera friendly, *Muntiacus vaginalis* were also frightened in three events, possibly by the sound of triggers from the camera traps. *Vulpes vulpes* appeared to be very aware of the camera traps, making frequent glances at the camera, and sometimes changing the direction they were walking after seeing a camera trap (seven events).

Spraying of urine and rubbing of anal glands on a tree trunk by *Prionailurus bengalensis* and *Catopuma temminckii* (Figure B.1.6), respectively, were recorded in one event for each. Similarly, rubbing anal glands or anal parts were also recorded for *Ailurus fulgens* in three different events (two in the daytime and one at night time) on the same part of a tree trunk during the winter season (Dec, Jan & Feb) (Figure 3.7), their mating season. The mating behaviour of a pair of *Hystrix brachyura* was also recorded during spring (April). This pair was frequently captured at the same location and based on the photo record, the male chased the female for approximately two minutes before mating took place.

Figure 3.7: The red panda in the left photo is sniffing on a branch of a tree, later s/he is rubbing his/her anal part on the same spot of the tree.

3.5.2 Wildlife distribution and relative abundance

Distribution

The cameras were mostly concentrated in the temperate region during the study period although the camera days/station between the temperate and sub-alpine zones were very similar, i.e. 29 days and 27 days, respectively. The total camera trap days in the temperate, sub-alpine and alpine survey zones were 2,377 (82 locations), 589 (22 locations) and 48 (3 locations), respectively.

Table 3.5: Number of independent captures, capture frequency (number of photos/1000 trap nights), photographic rates, major habitats occupied and recorded altitudinal rages of the medium-large-sized mammal species confirmed in the study area in eastern Nepal.

Species	Winter Season	Spring Season	Photo-rate (days/capture)	Major habitat occupied[1] (camera station)	Site[2]	Altitudinal range (m)		
Carnivora						**This study**	**Nepal[3]**	**Global[4]**
Ailuridae								
Red panda *Ailurus fulgens*	21 (15.3)	7 (4.3)	108	T (12), S (4)	I, P, T	2,100-3,400	2,210#-?	2,500-4,800

Felidae								
Common leopard *Panthera pardus*	1 (0.7)	4 (2.4)	603	T (4)	I, P	2,000-2,950	< 4,400	0-5,200
Asiatic golden cat *Catopuma temminckii*	5(3.6)	1 (0.6)	502	T (5)	I	2,400-2,500	1,000-3,000	0-3,738
Marbled cat *Pardofelis marmorata*	1 (0.7)	-	3014	T (1)	P	2750	< 2,500	0-2,500
Leopard cat *Prionailurus bengalensis*	23 (17)	18 (10.9)	74	T (14), S (5) & A (1)	I, P, T	1,900-4,250	200-3,000	0-3,240
Ursidae								
Himalayan black bear *Ursus thibetanus*	1 (0.7)	1 (0.6)	1507	T (2)	I, T	2,100-2,900	1,400-4,000	0-4,300
Canidae								
Red fox *Vulpes vulpes*	32 (23.2)	-	94	S (1), A (3)	T	3,950-4,350	3,000-5,500	0-4,500
Mustelidae								
Yellow-throated marten *Martes flavigula*	5 (3.6)	13 (7.9)	167	T (9), S (4)	I, P, T	2,000-3,350	100-3,100 3,252-4,510*	0-4,510
Viverridae								
Himalayan palm civet *Paguma larvata*	1 (0.7)	1 (0.6)	1507	T (2)	I, P	2,350-2,750	200-2,200 150-1,400^{+}	20-2,700
Prionodontidae								
Spotted linsang *Prionodon pardicolor*	1 (0.7)	1 (0.6)	1507	T (2)	I	2,450-2,500	130-2,745¤	150-3,308
Cetartiodactyla								
Cervidae								
Northern red muntjac *Muntiacus vaginalis*	82 (59.6)	184 (111.8)	11	T (56), S (12)	I, P, T	1,900-3,500	63-3,500	0-3,500
Bovidae								
Himalayan serow *Capricornis thar*	5 (3.6)	2 (1.2)	431	T (8)	I, P, T	2,450-3,000	500-3,050	300-3,000
Himalayan goral *Naemorhedus goral*	1 (0.7)	4 (2.4)	603	T (3)	I, P, T	3,100-3,400	300-3,000	900-4,000
Suidae								
Wild boar *Sus scrofa*	22 (16.0)	39 (23.7)	49	T (20), S (6)	I, P, T	2,100-3,450	63-4,000 120-4,200^{+}	0-?
Primates								
Cercopithecidae								
Assam macaque *Macaca assamensis*	6 (4.4)	7 (4.3)	232	T (9)	I, P, T	2,150-2,950	200-2,750	100-4,000
Rodentia								
Hystricidae								
Himalayan crestless porcupine *Hystrix brachyura*	7 (5.1)	23 (14.0)	100	T (4)	P, T	2,550-2,900	> 3,000	0-1,500
Sciuridae								
Flying squirrel	6 (4.4)	-	502	T (2), S (1)	I, P	2,400-3,365	-	-

-

[1]T: Temperate, S: Sub-alpine; A: Alpine
[2]Site: I-Ilam, P-Panchthar & T-Taplejung
[3]Nepal's altitudinal range assessed from Baral and Shah (2008), unless otherwise indicated
[4]Global range was accessed from IUCN Status ver. 3.1 as of 15 November 2018 from IUCN (2018) https://www.iucnredlist.org/
[#]Accessed from Bista et al. (2017)
[*]Accessed from Appel and Khatiwada (2014), the global highest-elevation record for the species
[+]Accessed from Katuwal et al. (2018)
[¤]Accessed from (Ghimirey et al. 2017)
-Not applicable

The altitudes and numbers of detected mammal species were inversely proportional in the study area. Among the 23 recorded mammal species (Table 3.5), 20 species were recorded in the temperate habitat followed by 10 in the sub-alpine habitat and five in the alpine habitat. Among the recorded felids, the leopard cat had the widest altitudinal distribution, 1,900 m to 4,250 m, and occurred in all kinds of habitat (temperate, sub-alpine and alpine) with the highest occurrence in the temperate region (Table 3.5). The cat was recorded in an alpine habitat with small rhododendron bushes in a rocky area during winter (January). Other felids were only recorded from the temperate habitat. The wild animals with the widest distribution range recorded were red muntjac (1,900-3,505 m), yellow-throated marten (2,000-3,350 m), wild boar (2,100-3450 m) and red panda (2,100-3,400 m).

Red panda:

The records of red panda were obtained from 16-camera trap locations (10 in winter and 6 in the spring survey) over the entire study period. The higher number of records during the winter survey was from Ilam district, which was due to the selection of the camera trap sites targeting red pandas as the survey also focused on monitoring them in Ilam. Based on the camera trapping photos, the distribution of red pandas ranged from 2,098 m to 3,400 m. The majority of the records (12) were from the temperate region and the remaining from the sub-alpine region (Table 3.5).

Relative abundance

Muntiacus vaginalis had the highest occurrence in the study area with a RAI of more than 50%. The first six most abundant species, including red panda in the study area, accumulated about 87% of the total RAI. The species with the lowest RAI values during the study period were mostly carnivores. The RAI during the winter and spring seasons (temporal difference) varied for almost all recorded species. The least abundant species had quite similar results for seasons (Figure 3.8).

Daily activity patterns of eight abundant species & comparison between winter & spring seasons

The TRAI provides a pattern of the daily activities of the eight most abundant species in the study area. These animals had different activity peaks during winter and spring, except for *Macaca assamensis,* which has similar activity patterns during both seasons. The macaque showed activity peaks during the periods from 10:00-1200 am and 12:00-14:00. Thus, they are diurnal in habit, commencing their day from 05:00 am during spring (April). The results showed that Ailurus *fulgens* and *Macaca assamensis* have similar daily activity peaks at 10:00-12:00 am and 12:00-14:00 during the winter season (Table 3.6). The activity patterns of *Vulpes vulpes* were only recorded during the winter season as the cameras were only set up at a high enough altitude during that season due to logistical issues. *Hysterix brachyura* is strictly nocturnal with activity peaks at 0:00-02:00 am and 02:00-04:00 am.

The pattern of activeness of *Muntiacus vaginalis* was almost similar for both seasons with a peak activity period at 18:00-20:00 but they were slightly more active during the winter than in spring (Table 3.8). They were active throughout the day in both seasons with a maximum activity during the daytime. The least active period for them was between 12:00-14:00 and 14:00-16:00. During spring *Sus scrofa* started their activity at 0:00 am, which was two hours earlier than in the winter.

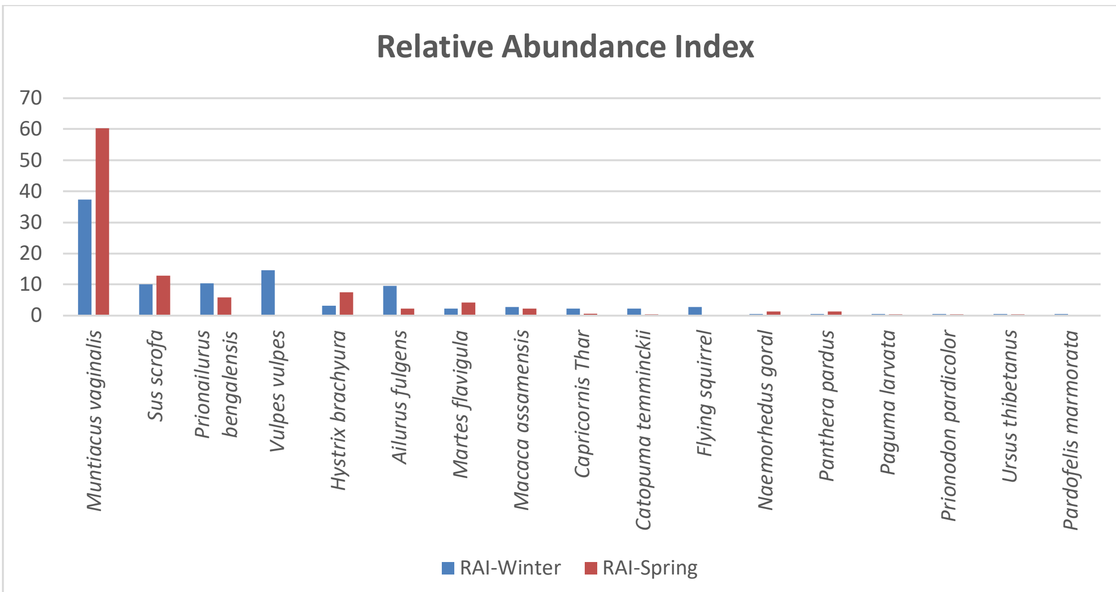


Figure 3.8: Relative abundance index (RAI) of all terrestrial mammalian species captured by infrared camera traps in southern Kangchenjunga Landscape in eastern Nepal throughout the study period and winter (Dec 2017 – March 2018) and spring (April – June 2018) season.

Hystrix brachyura stopped their activity at 04:00 am during winter, which was 2 h earlier than in spring. Their start time for activity in the evening was recorded at 18:00-20:00. *Ailurus fulgens* were active at midnight in both seasons. Their activity peaks were in the early morning (06:00-08:00 am in spring), morning (10:00-12:00 pm in both seasons), and afternoon (12:00-14:00 in winter). There were no records of activity for *Martes flavigula* after 18:00 until 02:00 am, with their peak period of activity between 16:00-18:00 for both seasons. The crop raider, *Macaca assamensis,* was also active in the early morning at 05:00 am during spring.

From Table 3.6, we can see the pattern of activity for different species over different time periods. The time periods (00:00- 2:00 and 12:00-14:00) were significantly different. The p-value for time period

(00:00-12:00) and (12:00-14:00) is 0.005 and 0.02 respectively. It shows that the activity peak period is between 00:00-12:00. other time periods (10:00- 12:00 and 18:00- 20:00) were not significant with p-value 0.09 and 0.07, respectively. Most of the species (*Ailurus fulgens, Muntiacus vaginalis, Sus scrofa, Macaca assamensis, Martes flavigula, Prionailurus bengalensis,*and *Hystrix brachyura*) were observed during these time periods.

Table 3.6: Comparison of daily activity patterns for most abundant species during the winter and spring seasons.

Species	**Activity peaks in winter**	**Activity peaks in spring**
Northern red muntjac *Muntiacus vaginalis*	16:00-18:00, 18:00-20:00	10:00-12:00, 18:00-20:00
Wild boar *Sus scrofa*	16:00-18:00, 22:00-24:00	12:00-14:00, 22:00-24:00
Leopard cat *Prionailurus benglensis*	0:00-02:00, 22:00-24:00	02:00-04:00, 20:00-22:00
Red fox *Vulpes vulpes*	04:00-06:00, 20:00-22:00	-
Himalayan crestless porcupine *Hystrix brachyura*	0:00-02:00, 02:00-04:00	02:00-04:00, 20:00-22:00
Red panda *Ailurus fulgens*	10:00-12:00, 12:00-14:00	06:00-08:00, 10:00-12:00
Yellow throated marten *Martes flavigula*	16:00-18:00	16:00-18:00
Assam macaque *Macca assamensis*	10:00-12:00, 12:00-14:00	10:00-12:00, 12:00-14:00

- Not recorded due to the absence of camera traps in their habitat in the spring season

Red panda and its probable predator, the Yellow-throated marten, have similar patterns of activity but the marten had a higher level of activeness. The recorded mammalian species are classified into nocturnal (active in dark), diurnal (active in daylight) and cathemeral (irregular in activity) based on their recorded activity periods (see table 3.7 for details).

Table 3.7: Classification of activity (nocturnal, diurnal and cathemeral) based on the activity periods of captured medium-large-sized mammal species.

Species	n	Photographic events (N)		Classification
		Nocturnal	Diurnal	
Muntiacus vaginalis	266	130	136	Cathemeral
Sus scrofa	61	28	33	Cathemeral
Prionailurus bengalensis	41	38	3	Strongly nocturnal
Vulpes vulpes	32	20	12	Mostly nocturnal
Hystrix brachyura	30	30	0	Strongly nocturnal
Ailurus fulgens	28	8	20	Mostly diurnal
Martes flavigula	18	2	16	Strongly diurnal
Macaca assamensis	13	1	12	Strongly diurnal
Capricornis thar	7	5	2	Mostly nocturnal

Flying squirrel	6	5	1	Mostly nocturnal
Catopuma temminckii	6	3	3	Cathemeral
Panthera pardus	5	2	3	Cathemeral
Naemorhedus goral	5	1	4	Mostly diurnal
Ursus thibetanus	2	1	1	Cathemeral
Paguma larvata	2	1	1	-
Prionodon pardicolor	2	2	0	Strongly nocturnal
Pardofelis marmorata	1	0	1	-

- Not sufficient data for classification

Nocturnal (18:00 pm - 06:00 am), diurnal (06:00 am – 18:00 pm)

The differentiation of activity patterns were classified in the following way: if ≥85% of records were between 18:00 pm and 06:00 am: strongly nocturnal; if 61-84% of records were between 18:00 pm and 06:00 am: mostly nocturnal; if 40-60% of activity was during day or night: cathemeral; similarly, if 61-84% of records were between 06:00 am and 18:00 pm: mostly diurnal; and if ≥85% of records were between 06:00 am and 18:00 pm: strongly diurnal.

Nocturnality of the abundant species

The nocturnality of the eight most abundant species is based on the night time relative abundance index (NRAI) (Table 3.8). Among the eight most abundant mammal species of the area, the Himalayan crestless porcupine was found to be the most nocturnal (100%) species. They were always active during night time. Leopard cats, red foxes and Northern red muntjacs also had a high degree of NRAI, at 92.7%, 62.5% and 48.9%, respectively. The Assam macaque had the lowest NRAI, with just 7.7%, indicating their diurnal habit. Wild boar, red panda and yellow-throated marten also displayed some nocturnality. The leopard cat was found to be always nocturnal during the winter season but two records of diurnal activities, at 09:43 am and 14:02 pm, were recorded during spring (Figure B.1.8).

While comparing the NRAI between the winter and spring seasons, leopard cat, wild boar and Northern red muntjac demonstrated quite similar patterns of activity. The red panda's night activity decreased sharply in spring compared with winter.

Table 3.8: Nocturnal Relative Abundance (NRAI) of the seven most abundant species during the winter and spring season and throughout the study period.

Species	NRAI (%)	NRAI-Winter (%)	NRAI-Spring (%)
Himalayan crestless porcupine, *Hystrix brachyura*	100%	100%	100%
Leopard cat, *Prionailurus benglensis*	92.7%	95.7%	88.9%
Red fox, *Vulpes vulpes*	62.5%	62.5%	-

Northern red muntjac, *Muntiacus vaginalis*	48.9%	46.3%	50%
Wild boar, *Sus scrofa*	45.9%	45.5%	46.2%
Red panda, *Ailurus fulgens*	28.6%	33.3%	14.3%
Yellow throated marten, *Martes flavigula*	11.1%	0%	15.4%
Assam macaque, *Macca assamensis*	7.7%	0%	14.3%

- Not recorded due to the absence of camera traps in their habitat in spring.

3.5.3 Alimentation Types

The recorded mammal species in the study area were categorised into carnivores, herbivores and omnivores based on their alimentation types for a general comparison of the ratios between predators (carnivores) and prey (herbivores and omnivores). The dynamics of animal populations are impacted by predation (Schaller 2009). The balance between the predator and prey population is important in regulating the population of both. The number of recorded carnivore species was higher in both seasons to the combined number of herbivores and omnivores.

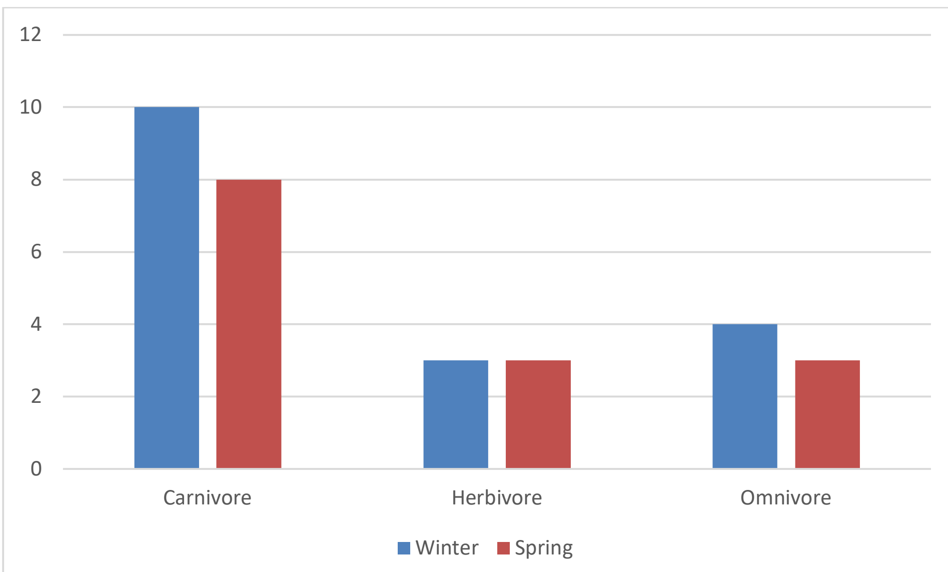


Figure 3.9: Distribution of alimentation types during the winter and spring season.

3.5.4 Ratio of Predator-Prey

The ratio of predator (carnivores) species to prey species (herbivores and omnivores) in the winter and spring were 10:7 and 8:6, respectively (Table 3.9).

Table 3.9: Ratio of predator and prey during winter and spring survey.

Alimentation Types	Number in Winter	Number in Spring
Predator	10	8
Prey	7	6

Table 3.9 shows the number of CHO in the winter and spring seasons. Although we have more predators in winter, the ratios do not change significantly. Here, during the winter 59% of the capture are predators and during the spring, it is 57% which are very similar.

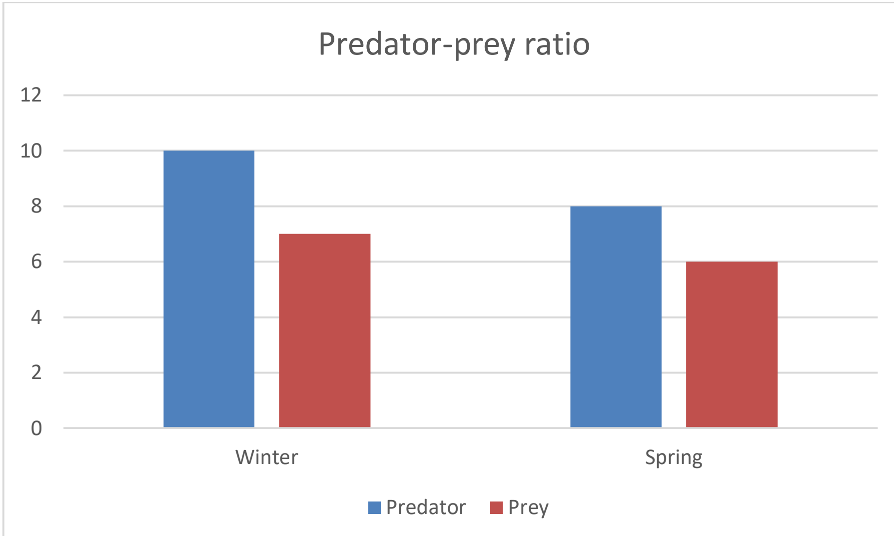


Figure 3.10: Predator-prey ratio during the winter and spring season.

3.5.5 Functionality of Camera traps, human error and theft

All the camera traps worked well during the period of study. Two Bushnell cameras were defective due to short-circuiting while being transported with batteries loaded. The field biologists forgot to turn on three camera traps at the time of installation and one camera after checking it in a one-week period. The data from three camera traps (96 camera days) were accidentally erased by an FG in Phalaicha while checking them using a smart-phone. One camera trap was not set at the proper height and orientation and it took only images of ground vegetation. The most common error on the camera's setting function was about the time setting using the 24 h time format, which led to confusion about AM and PM. One camera trap was dislocated by a yak in the forest of Phalaicha. A memory card and a pair of camera traps (Browning) were stolen from Ilam in the winter survey and from Taplejung in the spring survey, respectively. All of these aforementioned eleven camera locations caused a loss of data amounting to 284 camera days.

The camera traps located in the remoter alpine region for longer periods were accompanied by a warning message specifying that the devices were being monitored by satellite technology. These cameras were safe to leave for a month without any intermediate monitoring.

3.6 Discussion

The study area in eastern Nepal is outside of the network of the current protected areas in the country. Different forest management systems (community forest, religious forest, private forest, and traditional forest management system) were prevalent in the area but all systems focused more on management for production and utilisation than conservation hampering biodiversity. The area is a major habitat for the endangered red panda, the focal species of the area and many other endangered species. The Red Panda Network has been conducting community-based red panda conservation in the area for a decade and it has proven to be successful in spreading conservation awareness about the species among the local community people (Sharma et al. 2017). During the study, red pandas were detected in the area, along with 22 other species of mammals (small-large-sized) (Table 3.2). The presence of nine globally threatened mammals in the study area indicates its importance for biodiversity conservation. The assemblage of mammal species in the study area is quite similar to those recorded in the Makalu Barun National Park (17 species) by Ghimirey (2010) and in the Kangchenjunga Conservation Area (19 species) by Carpenter et al. (1995). My study provides the first baseline on the coexistence of a terrestrial mammalian community in the temperate broadleaved forest in eastern Nepal, a part of biodiversity-rich Eastern Himalaya.

3.6.1 Species Diversity and Distribution

During the 1,402 camera trap days in the winter survey, 220 independent captures of 17 medium-large-sized terrestrial mammals were recorded. Similarly, during the 1,612 camera trap days in the spring survey, 305 independent captures of 14 medium-large-sized terrestrial mammals were recorded. Despite the lower number of species captured during the spring survey, the number of independent records was higher than in the winter survey. This might signify that the wild mammals are more active in spring than in winter. Marbled cats, red foxes and flying squirrels were entirely absent during the spring survey. There was a valid reason for not capturing these species in the spring survey because the marbled cat was an elusive felid species with a low capture rate throughout its range (Azlan and Sharma 2006, Cheyne and Macdonald 2010). It was captured only once during the winter survey of this study. The red fox was not recorded during the spring survey when all camera traps were set below 3,500 m in altitude and all those during winter were captured around and above 4,000 m in altitude. Flying foxes were chiefly captured from camera traps placed inside dense forest areas for monitoring red panda during the winter survey.

Besides generating the general species diversity of the study area, this study was also remarkable due to the number of first records of species in the area. The photo record of a marbled cat was a first for Nepal, along with first records of the Asiatic golden cat, spotted linsang, and dark coloured barking deer in the Kangchenjunga Landscape. The spotted linsang was less likely to be recorded with direct sightings and was not possible to obtain confirmation by an indirect survey like sign detection (IUCN 2018). Among the six reported felidae from the area (Chaudhary et al. 2015), only four (leopard, Asiatic golden cat, marbled cat and leopard cat) were detected in this study. The two felidae species not present were the clouded leopard and jungle cat. The clouded leopard was mostly arboreal and also had a low capture rate in other studies (Ghimirey et al. 2013) and the jungle cat preferred habitats near to human settlement and cultivated land (IUCN 2018). Other wildlife species reported from the area: Dhole *Cuon alpinus,* Grey wolf, *Canis lupus*, golden jackal, *Canis aureu,* Nepal grey langur, *Semnopithecus schistaceus* and Musk deer, *Moschus* sp. were entirely absent from this survey. Only one canidae species, the red fox, was captured.

Semi-structured interviews (not included in this thesis) with one hundred local community people (44 from Ilam, 18 from Panchthar and 38 from Taplejung) conducted during the study period, revealed that the golden jackal has been extirpated from the area due to illegal poaching and snaring for the 'medicinal' use of its meat and bones. A tribal people, called *Bantar* from the Terai region of Nepal, were responsible for the mass killings of the jackal from the area approximately one and a half decade ago. They used snares, traps, and poison to kill the jackals and also used mimicry jackals for attracting them to trap. The species was recorded in the adjacent Khangchendzonga Biosphere Reserve in Sikkim, India with a photo rate of 1407 days/capture (Sathyakumar et al. 2011b). According to the local people, the grey wolf has vanished and returned to the area time and again. They also reported poisoning of the grey wolf by herders as they depredate livestock, and this is similar in Sikkim and Bhutan (Bashir et al. 2014). A small area in the sub-alpine and alpine regions of the probable musk deer habitat was covered by only four cameras for two weeks during the survey, which did not yield any photos of the species. Local people also reported high poaching threats to musk deer in the area. Both of the aforementioned species were recorded in the Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011b, Bashir et al. 2014). Low camera recordings in the sub-alpine and alpine regions of my study area would be a probable reason for not capturing them. The low record of Himalayan black bears in winter could be due to winter denning (hibernation) (IUCN 2018) although the records during the spring were also low, with one event only. Traps (old, dismantled, and fresh) for bear were observed throughout the study area. This also indicates that the poaching pressure for bears was prevalent and of a high scale in the area.

The clouded leopard has been reported from KBR in Sikkim (Sathyakumar et al. 2011b), which has a similar kind of habitat to this study. Since they were mostly arboreal in nature (Sunquist and Sunquist 2002) they might be undetected in my study area. The failure to record clouded leopard in my camera trapping study does not necessarily indicate that the species was not present in the area. This was also supported by a report of poaching of a clouded leopard in Surungkhim village in my study area a few years ago (pers. comm. K. Rai, April 2018). Cameras can be placed in specific areas to increase the probability of recording habitat specialist species (Tobler et al. 2008)

An increase in altitude also results in changes in the condition of a habitat (low temperature, harsh climate and minimum resources), affecting the distribution the mammals in Himalaya (Sathyakumar et al. 2011b). The number of species reduced with increasing altitude in my study area (20 species in the warm temperate region, 10 species in the moist sub-alpine region and five species in the relatively colder alpine region). The leopard cat's upper elevation record of 4,250 m in the study was higher than the IUCN published upper elevation limit of 3,240 m, which was from the Makalu area of eastern Nepal (IUCN 2018). Although (Sunquist and Sunquist 2002) mentioned that the leopard cat did not inhabit cold steppe grasslands and treeless areas, it was found in an alpine tree-less area. The highest photo-capture rate of leopard cats in the temperate forest, which was also near to human settlements, might be due to its high tolerance level to anthropogenic disturbance (Azlan and Sharma 2006). The documentation (photo capture) of red muntjac (3,505 m) and Himalayan crestless porcupine (2,910 m) were also higher than the IUCN published upper elevation limit. This generally indicate the inadequate past surveys of the species in their region.

The lowest altitude record for red panda in the study area was at 2,098 m during the spring survey in the month of April, which was lower than the IUCN published lower elevation limit of 2,500 m (IUCN 2018) and 2,210 m in Ilam in east Nepal (Bista et al. 2017). But signs of red panda were also observed as low as 2,000 m in altitude in a field survey in Jogmai village, Ilam (Sonam Lama, pers. obs., 2009). In the adjacent Singalila National Park, it was reported to be sighted at 2,400 m, as the lowest altitude, by Pradhan et al. (2001a). They were found to be more abundant in the temperate forest region than in the sub-alpine region with no records in the alpine region, as they required trees because of their arboreal nature (Hodgson 1847, Choudhury 2001) and bamboo to forage on (Yonzon and Hunter Jr 1991). The scent markings by red panda were recorded in three different events during winter, which also coincided with the mating period reported by Yonzon (1989), in the wild in Nepal, and Reid et al. (1991), in China.

3.6.2 Relative Abundance

The RAI, TRAI and NRAI, developed by Liu et al. (2013), calculated the abundance of all recorded species and the overall daily activity pattern, and night time activity pattern, of the abundant species. This calculation used the number of captures of a species against the total captures for all species although some other studies used trap nights for calculating abundance (Azlan and Sharma 2006, Sathyakumar et al. 2011b, Lahkar et al. 2018, Lama et al. 2018). Herbivore species, like red muntjac, and omnivores, like wild boar and porcupine, were more abundant than carnivores in the area. For the TRAI and NRAI to measure the daily and night time activity pattern I used 2 h intervals, the same as Liu et al. (2013) and Sathyakumar et al. (2011b), in a similar habitat area, and also to allow enough accumulation of activity in recorded events. But Azlan and Sharma (2006) and Kawanishi and Sunquist (2004) used 1 h intervals. For the calculation of the nocturnality of the species, the night time period was considered to be from 18:00-06:00, based on field experience and the sunrise and sunset data from the study area obtained from (Weatherspark.com 2018). This was also chosen as night time by Lynam et al. (2013)

and Azlan and Sharma (2006). The relative abundance was the simplest method of calculating wildlife abundance where the identification of an individual animal of a species was not possible or feasible (Liu et al. 2013), and this served as a database for future research (Lahkar et al. 2018).

The relative abundance of red muntjac was also higher in another study in the western mid-hills of Nepal (Appel et al. 2012) and Sikkim (Sathyakumar et al. 2011b). Similarly, the abundance of leopard cat was higher than other felids in the same study, in Nepal, and a study by Sathyakumar et al. (2011b), in Sikkim. According to the relative abundance index, yellow-throated martens and leopard cats were the major predators of the sub-alpine region. Similarly, yellow-throated martens, leopard cats and Asiatic golden cats were found to be major predators of the region, overall. The relative abundance indices of ungulate prey indicated that red muntjac were a major prey ungulate in the sub-alpine region, and red muntjac and Himalayan serow in the temperate region. Wild boars were also common in temperate and sub-alpine regions for larger predators like the common leopard. The largest predator of the temperate region, the common leopard, was not abundant in the area so that could be one of the reasons for the high abundance of red muntjac.

The higher capture rate for red panda during the winter season rather than in spring season was due to the intentional placement of the camera traps in areas of red panda movement higher camera trap days in winter. Camera traps in Ilam during winter were placed to monitor red panda that were always in pairs, one in the tree canopy and one in the ground when choosing the best place for locating red panda. Data from the ground cameras were also used in the analysis of mammalian diversity in the area. These biases might have resulted in the high capture rate of red panda during winter season rather than in spring (Table 3.4). However, the capture rate of the species during the spring season was also satisfactory despite its small body size, being a habitat specialist in a bamboo forest, and mostly arboreal and shy in nature (Hodgson 1847, Yonzon and Hunter Jr 1991).

3.6.3 Activity Patterns

I assumed that the wild animals' field activity levels corresponded with the photographs taken by the camera traps (Kawanishi and Sunquist 2004). I only analysed the activity patterns of species where the photo capture had at least five captures in each season. The capture records were analysed for their activity patterns based on the activeness of the respective species. They were then classified into the categories of diurnal, nocturnal and cathemeral. Some of the recorded mammals (mostly cats) could be partly arboreal, and this hindered the recording of their arboreal activity as all the camera traps only recorded activity at ground-level.

The seasonal activity pattern of the time period for some species in my study could not be reliable, as the data were generated from as few as five event records. A reliable statement about the time of activity would be in the cases of *Muntiacus vaginalis* (n=266), *Sus scrofa* (n=61), *Prionailurus bengalensis* (n=41), *Vulpes vulpes* (n=32), *Hystrix brachyura* (n=30), and *Ailurus fulgens* (n=28) (also check with the activity from chapter 4) as they provided a higher number of capture events and rates. Red pandas were found to be active during the day and night, with an overall activeness of 56% of the time (Yonzon and Hunter Jr 1991). In my study, red pandas were mostly active (71.4%) in the daytime (Table 3.8), which agreed with the results of a radio telemetry study of red pandas in Wolong Reserve, China (Reid et al. 1991). Their peak activity was recorded from 10:00 am - 12:00 pm in both seasons. During spring, *Sus scrofa* began their activity 2 h earlier than in the winter. This is probably due to the warmer temperatures in spring than in winter. Among the felids, the leopard cat was found to be more nocturnal in habit than the other three felids, which was also validated by other studies throughout its range (Grassman et al. 2005, Azlan and Sharma 2006, Cheyne and Macdonald 2011, Lynam et al. 2013, McCarthy et al. 2015, Noor et al. 2017). Only two diurnal events (at 09:43 am and 14:02 pm) of a leopard cat have been recorded so far, which were not recorded in another study in eastern Nepal (Ghimirey et al. 2012) and by Banke and Bardia, for western Nepal (pers. comm. B. Bhandari, May 2018). Similar diurnal records between 07:00 and 111:00 for leopard cats were obtained from Bhutan (Thinley et al. 2015), India (Saxena and Rajvanshi 2014) and China (Jinping 2010). Their major diets of small mammals (Jinping 2010), especially rats and mice, were also found to be strictly nocturnal in my study.

Alimentation types and predator-prey ratio presented in my study will serve as a baseline for future comparison studies because both the predator and prey have an important role in balancing the ecosystem by controlling the unwanted pests by predating the weaker individuals. Their balance is important to function an ecosystem.

The population of the KL increases in a southerly direction (Chaudhary et al. 2015), as there are warmer climates and more arable land there. Similarly, the composition of the mammalian diversity was also found to be concentrated more in the lower region of my study area (ten species were found only in the temperate region – Table 3.4). Thus, this will create an overlapping of the habitat/resource use by wildlife, humans, and their livestock, which might create the potential for conflicts between them. This study provides the first evidence-based wildlife diversity study of their relative abundance, their seasonal activity patterns, and some parts of their behaviour in the non-protected temperate and alpine forest areas of eastern Nepal. The results from this study will be useful for the management of wildlife species in the area where most of the areas are dominated by humans threatening the future of wildlife with transhumance livestock rearing practices (Oli 2008), illegal poaching and unregulated extraction of forest resources (Chaudhary et al. 2015). The results from the activity patterns and distribution of wildlife in the study area will be helpful in devising mitigation measures for prevalent human-wildlife conflicts (Sherchan and Bhandari 2017) in the area.

The theft of camera traps and other accessories is a global problem with the additional loss of money and time and impacts on the design of the survey (Meek et al. 2018). The cases of theft are always higher than the cases of vandalism. The lost camera traps and memory cards in my study were from the areas that were near human trails and in the area of forests where people went to collect fodder and firewood. Meek et al. (2018) reported that 96% of the thefts happened within 50 km of human settlements.

If the main aim of a survey was inventorying species of an area, so only using a camera trap in a station was recommended for increasing efficiency and reducing costs (Tobler et al. 2008). Their data also suggested that the spacing of the camera traps and the area covered have a low level of impact on the results. Moreover, the habitat of all types in different altitudinal zones was covered to maximise the probability of capturing species that were more concentrated or restricted to one habitat, as suggested by Tobler et al. (2008).

3.7 Conclusions

Camera traps were an important non-invasive tool for research. The data generated with the help of camera traps can provide meaningful insights into the status of biodiversity in an area. This was the first camera-trap based terrestrial mammalian inventory in the Kangchenjunga Landscape of eastern Nepal. The winter and spring camera trapping from 2018 recorded 23 species of small-large-sized mammal species and 37 species of birds in the study area. The species with the highest abundance were the Northern red muntjac, wild boar, leopard cat, red fox, Himalayan-crestless porcupine, red panda, yellow-throated marten, and Assam macaque. The time-period relative abundance index and night-time relative abundance index demonstrated the daily activity patterns of the eight most abundant mammal species of the study area. Interestingly, the night-time relative index (NRAI) showed that red pandas and leopard cats were more active during the winter season than in the spring season, which was opposite to the remaining species, except for the red fox. The camera traps were set in the habitat of a red fox only during the winter.

These results will be a baseline for future research for similar kinds of habitat in Nepal and will be helpful in monitoring the state of mammals in eastern Nepal. In future, the results of relative abundance and the activity patterns can be compared with other studies undertaken in similar kinds of habitat using similar research questions. The camera trap survey was highly successful in capturing most of the species reported in the area. It also provided some of the first photographic records of mammals for the region, like an Asiatic golden cat and spotted linsang, and also the first photographic record of marbled cats and dark muntjacs in Nepal. Camera trapping was not only useful in capturing medium-large-sized mammals of the area but also in capturing other small mammals like weasels, pika, squirrels and rats. Despite expending substantial camera efforts, some of the reported species, such as the clouded leopard, dhole, and the grey wolf, were not recorded. A study on the ecological impacts of the local extirpation of the golden jackal in the area is necessary. The ongoing activities of hunting (the case of hunting of Himalayan serow) and snaring of wild animals should be controlled by the local government engaging the local community people.

Generally, the use of lures for camera trapping is not in practice in Nepal. The lures of apples, banana, biscuits with jam or peanut butter, urine of hyena, and its own pellets were used for cage trapping for 427 trap days in 188 scent and food stations in Langtang National Park of Nepal by Yonzon (1989) but all failed.

Few areas of forests in Nepal's mid-hills have been surveyed using camera traps other than the low-land Terai region for studying local species, like tigers and leopards. As camera traps provided first-hand and the most reliable evidence of the mammal species in an area, their use in studying wild mammals should focus on the mid-hills. The results from this study showcased the importance of unprotected forest areas and the need of conservation in the Kangchenjunga Landscape to develop it as a conservation corridor connecting the transboundary protected areas between Nepal and India. The information obtained on the distribution of the seven nationally data-deficient mammalian species from this study would be important information for updating the National Red List of Nepal (Jnawali et al. 2011).

The database from this study would be helpful to guide in the development of species-based conservation action plans, allocate research funding, and help devise creative ways on solving human-wildlife conflicts at the local level. Conservation of species depends on the will and interest of people. Knowing more about these appealing creatures will be helpful in generating public interest into them, which ultimately support in the survival and welfare of the creatures.

Chapter 4

Arboreal Camera Trapping of Red Panda in Eastern Nepal

4.1 Red panda and camera trapping

The use of camera trapping survey in studying red panda is rare (Williams et al. 2011). Red panda are mostly studied using the indirect sign survey method with the help of transect lines (Lama 2013, Meek et al. 2014, Bista et al. 2017). This type of study is limited to understanding the presence, distribution and habitat use of a species. Due to the nature of the indirect sign survey method, its use is limited and cannot be used to monitor red panda for activity patterns, such as the use of a specific latrine site by an individual or their probable aggregation patterns (Williams et al. 2011, Khatiwara and Srivastava 2014). The use of camera traps to study wild mammal populations is increasing (Karanth et al. 2006, Dhakal et al. 2014, Thapa et al. 2017). Camera traps are useful tool for monitoring activity patterns of terrestrial species, including nocturnal activity (Azlan and Sharma 2006) and measuring species richness of arboreal mammals (Bowler et al. 2017). Camera traps can even monitor small and arboreal mammals, like squirrels (Di Cerbo and Biancardi 2013) (and see Chapter 2).

Radio or satellite telemetry is another potential tool to use to study animal behaviour. However, telemetry requires a great amount of money and time and is invasive in nature. Radio telemetry studies has been used with red panda where the results on activity patterns in the wild differed from each other (Johnson et al. 1988, Yonzon 1989, Reid et al. 1991, Wei and Zejun 2011). In modern wildlife science, the use of non-invasive genetic analysis has been popular as the technique offers minimum potential negative effects to direct dealing with the endangered species (Janečka et al. 2011) but this one is also costlier.

Ground based camera traps placed in red panda habitat in India for monitoring other small carnivores have successfully captured the species (Ghose et al. 2014, Khatiwara and Srivastava 2014). The images obtained from camera traps can be used to identify individual red panda (Shrestha et al. 2015). Before employing camera traps on a long-term monitoring of red pandas with systematic and standardised survey method, a comparison of effective placement of the camera traps is necessary. Etiquettes on deploying camera traps in tree canopies should also be considered and synthesised since the red pandas are shy and very sensitive to human presence around their dens, especially during nursing of their cubs (Yonzon 1989).

4.2 Aim of the Study

The aim was to investigate the effectiveness of camera trap placement on detecting red panda for their monitoring.

4.3 Objectives of the Study

- To compare the effectiveness of the placement (ground-based vs arboreal) of the camera traps to capture the images of red panda.
- To assess the winter activity pattern and difference in the diurnal and nocturnal activity levels in red panda throughout the study period.
- To identify the probable predator species of red panda.

4.4 Materials and Methods

4.4.1 Study Area

My red panda dedicated camera trapping survey (dedicated survey hereafter) was concentrated in Ilam and a small portion of Panchthar district in eastern Nepal. The area of study (26.997930^0 to 27.108550^0 N and 87.907830^0 - 88.1020400 E) is above 2,000 m altitude. The study area covers the community forests and national forest areas of the north-eastern villages in the Ilam district, from Gorkhe in the east through Mabu to Maipokhari and a few portions of adjoining community forest areas of Sidin and Lungrupa villages in Panchthar district (See Figure 3.1 in Chapter 3). The study area is connected to Singhalila National Park (SNP) of West Bengal India throughout its eastern border, and by human settlements and cultivated land in the south and west.

The forests of the study area fall in the temperate and sub-alpine zones. The zonation of the vegetation in the study area is similar to the adjacent SNP with a similar altitudinal range. The vegetation classification of the area is Oak forest 2,600-2,800 m, broadleaved deciduous forest >2,800-3,100 m, broad-leaf coniferous forest >3,100-3,300 m and coniferous forest >3,300-3,600 m by (Pradhan et al. 2001a). This categorization of vegetation will be followed in this study considering the vegetation up to 2,800 m as Oak forest. The Oak forest in SNP is dominated by *Quercus pachyphylla, Schefflera rhododendrifolia, Rhododendron arboretum* with bamboo *Yushania maling* in the understory. The broad-leaf deciduous forest is dominated by *Sorbus cuspidata, Symplocus* sp., along with *A. maling* and *A. aristata* in understory. The both *Arundinaria* sp. are major food items in the area (Pradhan et al. 2001a).

Singhalila National Park's broad-leaf coniferous forest is dominated by *S. cuspidata*, *Acer* sp., *Q. pachyphylla* and *A. maling, A. aristata*, *Vitex erubescense* were the common shrubs in the area. In the coniferous forest region, *A. densa* and *B. utilis* were found to be abundant with other shrubs, like *A. aristata* and *R. campanulatum*. The temperature of SNP varied from 7° to 17° C during summer and 1° to 10° C during winter. The average temperature during summer and winter were 7° and 1° C respectively in the sub-alpine zone. Mean annual rainfall was reported as 3,500 mm (Pradhan et al. 2001a).

Free ranging cattle were observed throughout the study area. A large tract of forest (approximately 4.3 km^2 area) of Jogmai and Jamuna along the border with India was cleared and a Potato Development Centre was established for producing potato seed in Jaubari in 1967 (Thapa 2008). There are numerous cattle herder temporary camps and human settlements with a few houses throughout the study area. Approximately 50% of the houses and all of the herders are accompanied by at least one untied dog, which are the greatest predatory threat to the red panda (Williams 2004). Detailed information on season, people, their occupations, and forest management system are given in 3.3.1.

4.4.2 Time Schedule

Originally, this dedicated camera survey was targeted to finish during the winter season but, due to the low number of camera traps and also to cover other areas for mammalian inventory, it was not all finished in one period of study. However, the majority of the camera trapping sampling were covered during the winter season, starting from 24 December 2017. The installation of camera traps in the field was started from Gorkhe village and ended in Maipokhari village. Before starting the field work, camera traps handling, and setup training was provided to the field surveyors (FGs) (see 3.3.3).

4.4.3 Arboreal Camera Trapping Design for Red Pandas

Each sampling station was accompanied by a pair of camera traps operating independently. Prior to installation of a pair of camera traps in the field, approximately a day was spent searching for the best tree (see 4.4.4) for setting up a camera suitable for red panda. One camera was placed at ground level at the base of a tree or within a 50 m radius. A second camera was placed in the tree canopy. The distance between each camera trap location in each grid was 1 km. (Yonzon and Hunter Jr 1991) estimated a minimum home range of 1 km^2 for a female red panda. The camera traps were deployed for at least a month in one sampling location.

With the help of ArcGIS 10.2, the forest areas above 2,000 m in altitude were selected and a uniform grid of cells of 2 km x 2 km were imposed throughout the selected area. This resulted in 68 grid cells throughout the study area, of which 15 grid cells were sampled. The grid cells which were inside private forest, barren land or areas without any trees were omitted. The most suitable grids for a dedicated survey of red panda were selected based on red panda presence data collected by RPN thorough a community-based red panda monitoring program (Williams et al. 2011, RPN 2016a) and another study by Kandel (2009). The experiences of the FGs were vital in the selection process for the 15 cells. After locating the red panda latrine sites in tree canopies, cameras were installed so as not to disturb their latrine sites or block their way to the canopy. For safety purposes the single rope technique used by (Gregory et al. 2014) was adopted in the trees that required effort to climb. At least two people worked together when installing the cameras in field for safety purposes.

Camera traps in trees were placed at a height of around 5 m as this is the height mostly used by red pandas for defecation (Rijal 2008, Lama 2013). The cameras were not placed in trees above 10 m height. Their mean height was 6.12 ± 0.44 m from ground level. The height of the camera placement, orientation of the cameras, mounting base (tree trunk, branches), aspect of site and other ecological parameters were noted. For the ground-based camera trapping, camera traps were mounted on tree trunks at a mean height of 0.40 ± 0.06 m above ground level. The height of the camera here indicated the height between ground level and the camera sensor. Ground based cameras were set up to capture photos of all mammals, not just red panda. Ground herbs were cleared in front of each camera and bamboo stems were tied together. Camera traps were set to run continuously, and no baits were used to lure the red panda because the lures of apples, banana, biscuits with jam or peanut butter, urine of hyena, and its own pellets were used for cage trapping for 427 trap days in 188 scent and food stations in Langtang National Park of Nepal by Yonzon (1989) didn't work at all.

The leaves of the tree canopy around 1 m in front of the camera traps were cleared to reduce misfires and were also preferentially oriented towards the north and south to reduce misfire from the heat of sunlight (Wearn and Kapfer 2017), where possible. This clearance also reduced the fast drain of batteries and use of SD card memory space. Camera traps were placed horizontally, targeting along the branches. Only one camera trap was set vertically along a tree trunk. The checking of the camera traps was done in two-week intervals. The location of each sampling stations was obtained using a GPS receiver (Rino120 handheld GPS; Garmin International Inc., Olathe, KS, USA). A dozen of Bushnell® TROPHY® were used for the dedicated survey (see Table 4.1 for camera settings).

Table 4.1: The settings assigned to Bushnell® camera trap in studying red panda in eastern Nepal, in 2018.

Mode	**Image size**	**Image format**	**Capture number**	**LED control**	**Interval**	**Sensor level**	**NV Shutter**	**Camera mode**
Camera	20MP	Full screen	3 photos	High	03S	Auto	Auto	24 Hrs
Time stamp	**Sensor**	**Flash range**	**Night vision flash**	**Power supply**	**Trigger speed**	**Recovery time**	**Light source**	**Detection distance/sensor range**
On	PIR	100 feet	Low glow	AA (8)	0.2 sec	0.6 sec	Infrared LED	100 feet

4.4.4 Selection of trees for Camera Trapping Red Pandas

Areas of high human interference and free ranging livestock pressure were omitted to reduce the misfire of the camera traps. In the selected grids, a transect walk were done following the terrain contours at intervals of 200 m to identify trees that were actively used by red panda. Actively used trees were distinguished by the freshness of pellets and foraging marks. The most suitable trees selected had fresher pellets or other presence marks, with at least 50% canopy coverage, near to a water source, a high density of bamboo cover, and areas with fruiting Sorbus trees (Yonzon 1989, Pradhan et al. 2001a, b, Williams 2004). More trees were selected around or between the altitudinal range of 2,600 m – 3,000 m because the species has abundant distribution in that range in the study area (Williams 2003).

The presence of red panda in the area was easy to detect with the help of their active latrine sites as they usually defecate in a single place multiple times and sometimes by multiple individuals (Yonzon and Hunter Jr 1991). As the trees are the most favourable site of defecation for red pandas (Pradhan et al. 2001b, Williams 2004, Rijal 2008, Kandel 2009, Lama 2013, Bista et al. 2017), the most preferred species of trees with fresh latrines were selected for the camera trapping. Based on the different studies on red panda in the study area (Williams 2003, 2004, Rijal 2008, Kandel 2009, Williams et al. 2011), the most preferred tree species by red panda (*Lithocarpus pachyphylla*, *Rhododendron* sps., *Symplocos theifolia*, *Hymenodictyon excelsum*, *Machilus edulis*, *Sorbus cuspidate*, *and Acer* sp.) were chosen for placement of camera traps. The use of trees for defecation by red panda was also high in winter in the Ilam district (Williams 2004). A close water source is a prerequisite for red panda habitat because most of the red panda sign were encountered near to the water sources in Nepal, India, and Bhutan (Yonzon and Hunter Jr 1991, Pradhan et al. 2001a, Williams 2004, Rijal 2008, Kandel 2009, Dorji et al. 2012).

4.4.5 Distribution of camera traps locations

Camera traps were distributed from 2,310 to 3,370 m a.s.l. The distribution of cameras were nine camera locations up to 2,500 m, eight camera locations between 2,501 to 3,000 m and two camera locations between 3,001 m to 3,400 m a.s.l. The camera trapping started from end of December 2017. All the cameras were left in field during the winter season, except four pairs of cameras which were left in field from March to April 2018.

4.4.6 Data Analysis

The trap-days for each camera trap was calculated as the number of 24-hour periods. The start and end dates were accessed from the first and last photos of each camera trap as the photos of the person at the time of installation and removal of each trap were taken for reference.

Daily activity pattern of red panda

The time-period relative abundance index (TRAI) and night-time relative abundance index (NRAI) were calculated to assess the daily activity pattern and nocturnally of red panda. Days were divided into twelve periods of two hours each for TRAI and the periods from 18:00 to 6:00 were considered as night periods for NRAI following (Azlan and Sharma 2006) and based on the timing of sunrise and sunset by field observation. The calculation of TRAI and NRAI are described in 3.4.7, II) and III). One activity record of a panda which was recorded by both the arboreal and ground camera was eliminated during the calculation of the activity patterns of the species. There were five different individual records which were recorded by both the arboreal and ground camera traps during the entire study period.

A comparison of ground versus arboreal placement of camera traps detecting red panda

Data from 19 pairs of camera traps were used to monitor red panda and test the effectiveness of camera on photographing the red panda (target species). Photographs were classified as: 1) target species, 2) non-target species, and 3) false triggers. All other wild and domestic animals were non-target species. Photographs taken >30 minutes apart were considered to be of different individuals or 'independent events' and were filtered to remove the same species at the same camera to ensure the events were independent, using Camera Base (Tobler 2007). The 30 minutes time interval was considered to distinguish the independent events because all (except in one case but that was not used in this analysis) the photo records of red panda showed them spending less than 30 minutes in a tree or ground.

Generalised linear mixed effects models (GLMMs) and Linear mixed model (LMM) were performed to assess the differences in the placement of arboreal and ground-based camera. The maximum likelihood (Laplace approximation) was used to compare the models of the response variable (Independent events of target species). The false triggers data was approximately normally distributed because the average number of counts was large. As a result, LMM was used for this dataset. The software program R version 3.5.1 (Team 2018) list r packages used for an include/library/require command and read what is inside was used to fit both GLMMs analysis and LMM. During analysis, the camera placements (arboreal and ground) was used as fixed effect and the camera monitoring station was random effects.

4.5 Results

The average camera days for a pair of camera traps was 43 ± 2.8 days, ranging from 28 days to 78 days from 19 different camera locations. Among them, eleven pairs of camera traps took photos of red panda. Although, both arboreal and ground camera traps recorded photos of red panda, the arboreal cameras recorded more photos (89%) than the ground cameras (11%). The total camera effort for ground and arboreal camera was 1,620 trap days in total resulting in 59,342 photographs. Only 1.5% of the total photographs (903) were of red panda. Other recorded photographs were 5.8% other mammals, 3.5% birds, 2.2% livestock, 0.6% human, and 77.8% false triggers. The total independent events of ground and arboreal camera were 21 and 38 respectively, indicating the effectiveness of the arboreal camera traps (please see Table 4.2 for comparison of advantages of ground and arboreal cameras).

Ground based camera traps also recorded Asiatic golden cat *Catopuma temminckii*, Assam macaque *Macaca assamensis*, common leopard *Panthera pardus*, wild pig *Sus scrofa*, flying squirrel, Himalayan goral *Naemorhedus goral*, Himalayan palm civet *Paguma larvata*, Himalayan serow *Capricornis thar*, leopard cat *Prionailurus bengalensis*, Northern red muntjac *Muntiacus vaginalis*, Oranged-bellied Himalayan squirrel *Dremomys lokriah*, rat *Rattus* sp., Siberian weasel *Mustela sibrica*, spotted linsang *Prionodon pardicolor*, yellow-throated marten *Martes flavigula*, and domestic dog *Canis lupus familiaris*. Mammals recorded by arboreal camera traps were the Northern red muntjac, Flying squirrel, yellow-throated marten, orange-bellied Himalayan squirrel, rat, yellow-bellied weasel *Mustela kathiah,* and an unidentified species of bat (a complete list of recorded species in Appendix E). A red muntjac was also recorded by an arboreal camera that was orientated downward towards the ground. Yellow-throated marten, a probable predator of red panda (Reid et al. 1991), was recorded by the ground cameras (Appendix B, Figure B.1.11). Similarly, an arboreal camera trap also recorded marten and that site was frequently visited by red pandas (Appendix D, Figure D.2). At this site, the red panda was recorded in both the day and night-time whereas the marten appeared at this site at midday. The common leopard, another reported predator of red panda (Yonzon and Hunter Jr 1991) was also photographed by a camera trap. A domestic dog was photographed by a ground-based camera trap during the survey. The partially arboreal mammal (IUCN 2018), spotted linsang, was not recorded by arboreal cameras but was captured by a ground based camera trap. The highest recorded mammal species was the rat (strictly nocturnal), followed by orange-bellied squirrel, red muntjac, flying squirrel, leopard cat, and Asiatic golden cat.

Table 4.2: A comparison of advantages of ground and arboreal camera placement for monitoring red panda.

Ground-based camera traps	Arboreal camera traps
Good capture of side view of a red panda with whole body	Whole body with side view rarely captured
Recorded scent marking and sniffing on tree trunk before ascending the tree	Recorded scent marking and sniffing more frequently than ground cameras
Only recorded one to three photographs per events, minimum records of photos	Plenty of photographs of red panda recorded due to high activity in the canopy
Recorded low level of activity	Activities like grooming, sleeping, scent marking, sniffing were recorded for longer
Records with clear facial views and marks were low	Records of clear facial views and marks were high and good in quality

Individual facial marks from different events were not as comparable	Individual facial marks of a panda from different events were comparable and identical (Appendix D, Figure D.1)
The tail marks between individuals were comparable	The tail marks between individuals were comparable
Low level of false triggers of a camera trap	Very high false triggers due to the moving branches, leaves and sun-heat
Problem of very close up or half body parts was lower	Problem of very close up photos, sometimes only produced body parts
Low number of cameras checking and sniffing by a panda	High number of cameras checking and sniffing by a panda
No problem of over-exposure of photos	Few problems of over-exposure of photos when the pandas came to investigate the cameras

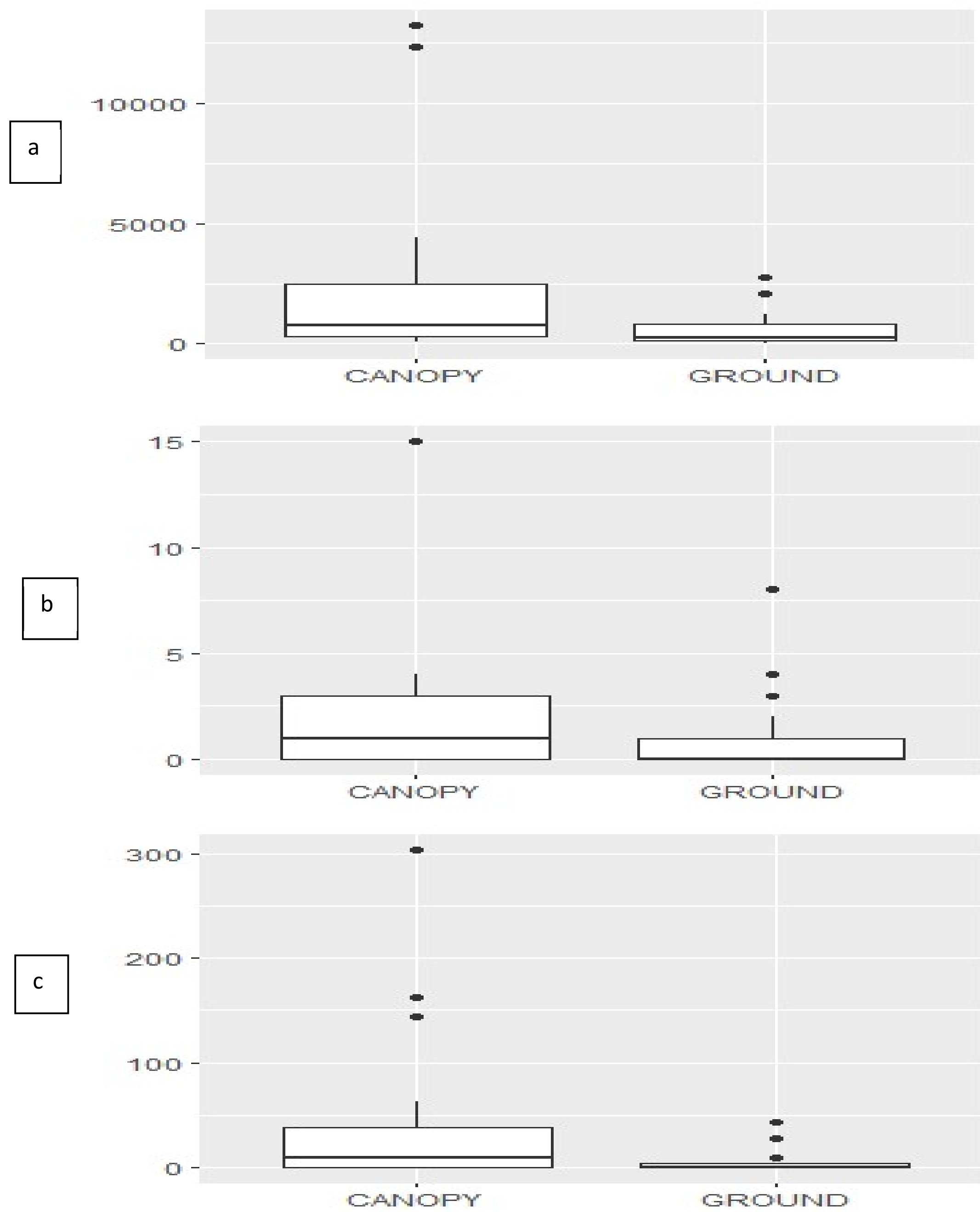
4.5.1 A comparison of ground versus arboreal placement of camera traps detecting red panda

In total, 59 independent encounters of red panda were captured (21 by ground cameras and 38 by arboreal cameras). Arboreal cameras captured significantly more photographs (target species, non-target, and false triggers) compared to ground-based cameras (Table 4.3, Figure 4.1a). Similarly, arboreal cameras provided significantly more independent events of target species than the ground-based cameras (d.f. = 1, 19, $P = 0.0292$) (Table 4.3, Figure 4.1b). Arboreal cameras were able to capture significantly more photographs of target species (Table 4.3, Figure 4.1c). However, there were more

Table 4.3: The details on number of photos obtained from ground and arboreal placement of Bushnell® camera traps in eastern Nepal, in 2018.

Placement	Target species (red panda)	Non-target species (other mammals)	Bird species	Livestock	Human	During Setup	False triggers	Total Photos
Ground	96	1,247	1,658	1,293	332	2,177	4,759	11,562
Arboreal	807	2,209	394	28	0	2,925	41,417	47,780

false triggers on arboreal cameras comparison to ground based cameras (d.f. = 1, P = 0.00045) (Table 4.3, Figure 4.1d). Cameras captured more photographs and exceptional images for activity study (tree climbing panda, more photos recorded, clear marks of face and tail, time-consuming activities like sleeping and grooming) of target species rather than ground camera. Non-target species (4.6% of all photos taken) recorded by arboreal cameras were rat, orange-bellied squirrel, flying squirrel, yellow-throated marten, bat and red muntjac. Only 0.9% of photographs taken by arboreal cameras were of birds. The false triggers from ground and arboreal cameras were 8% and 69.8% respectively.



d

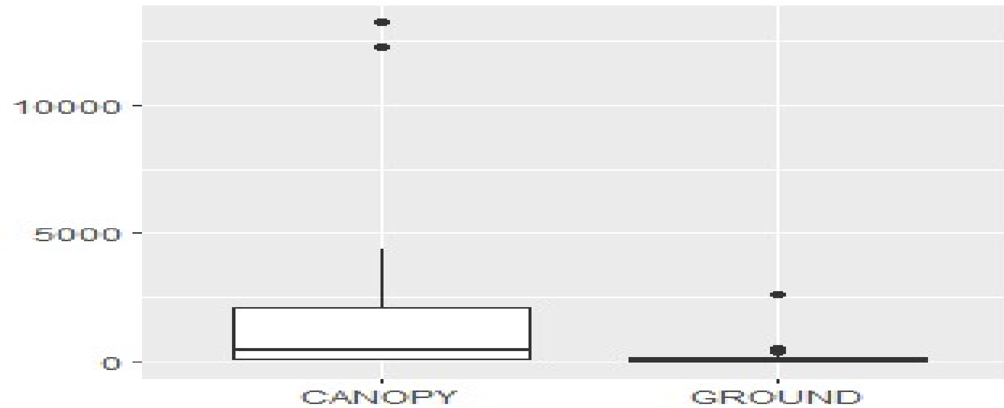


Figure 4.1: (a) Total photos, SE (Arboreal=880.46, Ground=170.62), (b) independent events of target species SE (Arboreal=0.787, Ground=0.464), (c) Total number of photographs of target species SE (Arboreal=18.12, Ground=2.55), (d) Total number of false triggers from ground and arboreal base camera SE (Arboreal=905.14, Ground=137.4). The dark line inside the box is median, the bottom and top line of box is 25th and 75th percentiles, the black dot are outliers, unequal box sizes is unequal variance.

4.5.2 Daily activity patterns of red panda

The highest activity peak time period for red panda was between 04:00 - 06:00 am with eight independent records. Among them five records were from the arboreal cameras. This was followed by 10:00 – 12:00 pm, and 12:00 – 14:00 pm with records of activity of seven events for each period. Other times of 14:00 – 16:00 pm, 08:00 – 10:00 am and 20:00 – 22:00 pm time period recorded five, four and four activity events, respectively. The recorded photographic events revealed that the red pandas were found to be active in every hour at least with one independent recorded event (Figure 4.2)

Overall, red pandas were found to be cathemeral in their activity pattern with 29 independent diurnal and 26 independent nocturnal records (please see table 3.7 for classification of activity into nocturnal, diurnal and cathemeral). The NRAI of the species was found to be 47%.

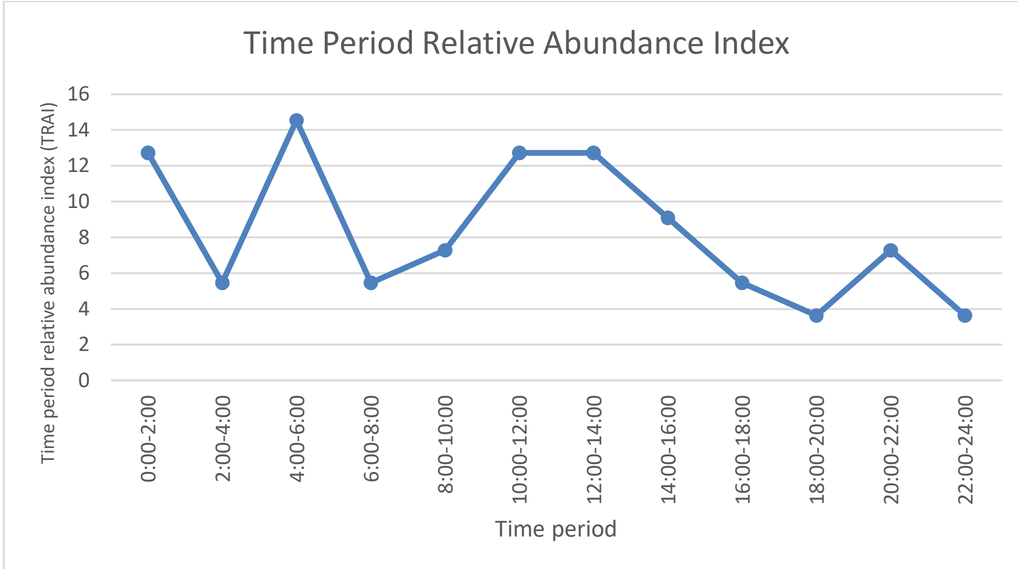


Figure 4.2: Daily activity patters of Red panda *Ailurus fulgens* recorded by camera trap in eastern Nepal.

4.6 Discussion

The ground-based camera trap recorded more species of other mammals than the arboreal camera, but the arboreal camera traps were more effective in recording red panda. This extra information from arboreal cameras allows for the collecting of more details about red panda behaviour and activity patterns. In one event, an arboreal camera recorded activities of a red panda for two hours and eighteen minutes. The panda was mostly sleeping in different postures (Figure B.1.3), curling its head with its tail, grooming itself, and sniffing the area and the camera.

The record of a yellow throated marten in a site frequently visited by a red panda in the tree canopy is consistent with it preying upon red panda as reported by Reid et al. (1991) in China. Roaming domestic dogs have been reported as a serious problem to the ground dwelling red pandas in the study area by (Williams 2004). The photographic record of a roaming domestic dog wandering through the forest in the study area is also consistent with the dogs venturing into the forest to hunt wildlife species. The abundance of common leopard in the study area was very low and the abundance of its ground dwelling prey species, such as red muntjac and wild boar, were high in the study area. The predation threat (Yonzon and Hunter Jr 1991) by the leopard to red panda may be low in the study area.

Arboreal dwelling monkeys of the area were not recorded by the canopy cameras. This is possibly by the low height of the camera in the tree, or cameras being installed on a tree trunk and the monkeys traveling via the tree canopies or due to the low density of monkeys in the area. The diversity of the arboreal dwelling mammals was found to be very low in the area. Rats were the most abundant recorded small mammal by the canopy camera which were strictly nocturnal in activity. Another abundant canopy dweller small mammal was the orange-bellied Himalayan squirrel, which was strictly diurnal in activity.

The total records of independent events of red panda were high in this dedicated camera trapping compared to the set up for the mammal survey (chapter 3). In this study the highest activity period of panda was recorded between 04:00 – 06:00 am in the early morning. The pandas were found to be active during all the hours of a day on this study. Despite being a bamboo specialist, red pandas stomach are simple and possess a short gastrointestinal tract with no caecum (Roberts and Gittleman 1984, Johnson et al. 1988, Reid et al. 1991). Activity pattern is an important aspect of animal behaviour and it is always related to metabolism and energetic constraints (Zhou et al. 2007). According to (Wei et al. 2009), panda only use 18-30% of the entire intake of dry bamboo matter that they consume. It is likely that a red panda adopt an adaptive strategy with frequent active periods to ensure their digestive tract is filled with bamboo (Johnson et al. 1988).

Activity rates of panda were found to be higher during spring, summer-and autumn seasons than in winter (Zhang et al. 2011). My study mostly took place during winter. Activity patterns of red panda in other seasons may be different. One of the lowest activity records of this study, 22:00 – 24:00 was also similar to the result of (Zhang et al. 2011). The highest activity period for my study, 04:00-06:00 am, differed from the Chinese study. In this study, red panda exhibited daily peak activity early in the morning and during daytime. It was found to be more active during the morning and dusk in China (Zhang et al. 2011). Similar to (Reid et al. 1991) and (Zhang et al. 2011), this study showed that the red pandas are more active during the day than at night. The comparison of the activity patterns with the red pandas in China may not be relevant due to the different climatic and topographic features in these regions. (Hodgson 1847) reported red panda to be more active at dusk, dawn, and night with observations in Nepal. The reason behind the red panda being active most of the time active is to forage the low quality diet, bamboo (Yonzon and Hunter Jr 1991).

This study showed that the cameras placed in the canopy were more effective in capturing red pandas than when placed on the ground. In a study to detect cats and mustelids in New Zealand, Nichols et al. (2017) compared the horizontal and vertical orientation of camera traps and found that the horizontally placed cameras were most effective. Almost all the camera traps, except two arboreal camera traps of this dedicated study were placed with horizontal orientation. Among two of the vertically oriented camera traps, one successfully recorded a red panda. The vertically oriented camera recorded a tree climbing and head first descending red panda from a tree. This indicates that vertically oriented cameras are also useful in recording red panda.

Despite the high number of photographs of red panda taken by arboreal cameras, a few of them had a problem of only showing some parts of their body. This made comparing with other panda photos for identification difficult. The issue was created due to the shorter field of view of the camera traps. In future survey, priority should be given for the places with the wider and longer field of view for placing arboreal camera traps.

Red pandas sometimes investigated the arboreal cameras, usually by sniffing them. They did not seem to be frightened by the cameras. In one event a panda slept in front of a camera for two hours and eighteen minutes with lots of activities. They did not physically interact with cameras unlike giant pandas in China, (Li et al. 2010). Camera traps appear to be useful in documenting wildlife in the canopy as they do not unduly stress or injure animals (Gregory et al. 2014).

Most of the false triggers for both ground and arboreal cameras occurred during the day time due to leaf movements and sunlight temperature changes. The false trigger of 69.8% from the arboreal cameras of this study was lower than the study by Gregory et al. (2014), which had 98% false triggering. This could be reduced by clearing the vegetation in-front of cameras and preferably orienting them towards north or south direction. This will reduce false triggering of the camera traps by the direct sunlight during sunrise and sunset (Si et al. 2014).

4.7 Conclusion

The arboreal camera traps were very effective in recording more independent events of red panda, allowing more accurate visualisations of its activity patterns. As red panda is an arboreal mammal, the arboreal camera traps were effective in recording their different activity patterns.

This study showed that the arboreal camera traps are liable to record far more photographs of red panda than ground-based cameras. Arboreal camera traps can be used to predominantly target red panda to study its behaviour, activity pattern, and its possible predators' presence and behaviour. Canopy based cameras are efficient at capturing clearer image of red panda with sharp facial marks which can be used in differentiating individual animals. While ground-based camera can be used on recording the presence of red panda and for assessing mammalian diversity of an area.

Chapter 5

First photographic record of marbled cat *Pardofelis marmorata* Martin, 1837 (Mammalia: Carnivora: Felidae) in Nepal

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5.1 Abstract

The marbled cat *Pardofelis marmorata* is a Near Threatened small felid. The cat's presence in Nepal is based on an anecdote. A camera trap-based study to access diversity and abundance of terrestrial mammals in eastern Nepal accumulated 3,014 camera trap days and resulted in 5,176 photographs of 17 medium-large sized mammal species. Amongst them, a marbled cat was captured at a single camera trap station in January 2018. The camera trap-capturing the marbled cat was located in the secondary forest at an alti-tude of 2,750 m a.s.l., dominated by free-ranging cattle close to a permanent human settlement (1.4 km) and a temporary cattle herding camp (0.4 km). This is the first photographic evidence of a marbled cat in Nepal. In this survey, we also recorded three other felid species: common leopard *Panthera pardus*, Asiatic golden-cat *Catopuma temminckii* and leopard cat *Prionailurus bengalensis.* We recommend detailed year-round camera trap surveys in the mid-hills of eastern Nepal along with research on adaptation of the small felids to human-dominated areas and assessment of immediate threats for preparing sound conservation management plans of the marbled cat and its sympatric species. Initiation of conservation programmes engaging local *dokpa* (herders) is necessary.

5.2 Introduction

The marbled cat *Pardofelis marmorata* Martin, 1837 is categorised as 'Near Threatened' in IUCN Red list of Threatened Species (Ross et al. 2016), and nationally data deficient in Nepal (Amin et al. 2018; Jnawali et al. 2011). The marbled cat, listed in CITES Appendix I, is a member of the Felidae family along with 14 Genera and 42 species of cats (ITIS, 2018). This small wild cat is a member of the bay cat lineage along with Asiatic golden cat *Catopuma temminckii* and bay cat *Catopuma badia.* The marbled cat is similar in colouring to the clouded leopard *Neofelis nebulosa,* with dark blotches, stripes and spots. An arboreal cat with great climbing skills (Mohamed et al. 2009; Sunquist and Sunquist 2017), it is little studied (Sanderson and Watson 2011; Sunquist and Sunquist 2014). The marbled cat is slightly larger and more slender than a domestic cat (Blanford 1888-91), with a long and bushy tail that is similar in length to the cat's body. Their sides and back are prominently smudged with irregular, large, and dark-fringed markings. Black dots are embellished on legs and underparts, and the tail has proximal black spots and distal rings (Sunquist and Sunquist 2017). Out of the two distinct subspecies of marbled cats, *Pardofelis marmorata marmorata* and *Pardofelis marmorata charltonii* (Kitchener et al. 2017), the latter is distributed from the foothills of Nepal, through Sikkim, Assam, and into upper Burma (Pocock 1939). *Pardofelis marmorata charltonii* has a much thicker and longer coat than *P. m. marmorata*, with a rich ochreous-brown colour (Pocock 1939).

The forest-dependent marbled cat is distributed throughout Southeast Asia, from the Himalayan foothills of India, and Bhutan to China, and then southward through to Malaysia and Indonesia. The marbled cat has been recorded in Bangladesh (Hance 2016; Khan 2015), Bhutan (Tempa et al. 2013) Brunei Darussalam (Ross et al. 2016), Cambodia (Gray et al. 2014), China (KFBG 2015; Wang and Wang 1986), India (Choudhury 1996), Indonesia (Cheyne and Macdonald 2010), Lao People's Democratic Republic (Johnson et al. 2009), Malaysia (Azlan and Sharma 2006), Myanmar (Zaw et al. 2014), Thailand (Grassman et al. 2005), Vietnam (Nowell and Jackson 1996). Although Nepal is noted as the western-most range in distribution for the marbled cat by the IUCN Red List (Ross et al. 2016) there has been no record of direct sighting or photo proof of the species in Nepal (Dahal and Dahal 2017).

The distribution map for the marbled cat shows Nepal's Nawalpur, west of Chitwan National Park (CNP), as the westernmost record of the species based on a single dead specimen record of the species (Ross et al. 2016). However, the species was not recorded from inside the park at that time. The nearest confirmed record to Nepal is from Khangchengdzonga Biosphere Reserve in Sikkim, India, and further south in the Manas National Park, in Assam, India. Despite many extensive camera trapping surveys in CNP and other parts of Nepal, there have been no records of live marbled cat (Dahal and Dahal 2017; Lamichhane et al. 2014; Lamichhane et al. 2016; Yadav et al. 2018). One skin of the species was collected by B. H. Hodgson and presented to the British Museum and labelled as 'Nepal' (Pocock 1939).

It is assumed that the skin might have been collected during his studies between 1823 and 1843. Blanford (1888-91) reported the marbled cat as present in Sikkim but not in Nepal. Similarly, a mammal survey report in Nepal by the Bombay Natural History Society found no evidence of the marbled cat in Nepal and speculated that Sikkim may have been the origin of the Hodgson's specimen (Hinton and Fry 1923). Pocock (1939) declared the claim of Blanford (1888-91) to be wrong without presenting any reasons. Horsfield (1856) only mentioned 'hilly region' not the area as the habitat of marbled cat in his catalogue of the collection of Mammalia from Nepal, Sikkim, and Tibet. Pocock (1939) also mentioned that the species was very hard to obtain for collection and seldom received alive by zoos. At that time, the people of Bombay Mammal Survey were not able to capture or buy a single animal from the indigenous people in Nepal, Sikkim, Assam, and Burma. This also indicates the potential rarity of the cat at that time.

The species is primarily found in moist and mixed deciduous-evergreen tropical forest and prefers hilly forests (Duckworth et al. 1999; Grassman et al. 2005; Holden 2001; Nowell and Jackson 1996). The marbled cat is also found in secondary and logged forest, clearing, mangroves and on the periphery of the oil palm plantations (Bernard et al. 2013; Hearn et al. 2016; Ross et al. 2010). The marbled cat's diet likely consists of squirrels and rats and birds up to the size of pheasants (Nowell and Jackson 1996; Pocock 1932). This matches what is known from an individual in captivity (Sunquist and Sunquist 2017). Additionally, there is a report of the hunting of a juvenile male Phayre's leaf monkey by a marbled cat in Thailand (Borries et al. 2014).

The species occurs in isolated and fragmented habitat patches in some part of their distribution range (Ross et al. 2016). The loss of the habitat caused by deforestation is considered as a major threat for the species. Indiscriminate snaring is also common throughout much of its range and is likely a threat to the species (Ross et al. 2016). Body parts of this species were also reported from an illegal market of Yunan, China (Haibin and Kunming 1999). The marbled cat is also hunted for meat (Selvan et al. 2013b) and for socio-cultural rituals by some tribal groups in India (Selvan et al. 2013a). Among the numerous confiscations of leopard pelts, there is no record of marbled cat pelts in Nepal (CIB 2018).

Camera traps have been recording and providing new information on distribution and aspects of ecology, in recent times, of small and medium-sized wild felids throughout Southeast Asia, such as the marbled cat (Tempa et al. 2013; Thinley et al. 2015; Wibisono and McCarthy 2010). Camera traps provide absolute evidence that a species is present in an area. The success of image capture for cats is dependent on a number of life history traits.

The first ever camera trap photograph of a marbled cat was captured during daylight hours (Table 5.2) in Huai Kha Khaeng Wildlife Sanctuary in Thailand in 1994 (K. Conforti. pers. comm. as cited in Nowell

& Jackson, 1996). Similarly, the first photograph of a marbled cat in the wild was taken in Khao Yai Wildlife Sanctuary, Thailand in 1993 (Jackson 1997).

5.3 Methodology

A camera trapping study was conducted in non-protected forest areas of the Kangchenjunga landscape, bordering India on the eastern side, connecting the Singhalila National Park, Barsey Rhododendron Sanctuary, and Khangchendzonga Biosphere Reserve, in far eastern Nepal (26^0 59’ 6.159” - $27^0$25’57.969” N and $87^0$51’24.084” – $88^0$6’34.282” E). The elevation ranges between 2,000 to 4,360 m above sea level (m a.s.l.) covering about 520-km^2 area. The study area has been proposed as a conservation corridor to connect Nepal’s Kangchenjunga Conservation Area (KCA) to these Indian conservation areas (Chettri et al. 2007). Monsoonal rain decreases from the beginning of October and the colder days increase in frequency, with the leaves of the deciduous hardwoods starting to fall by the end of November. This study area has been identified as a last remaining tract of Eastern Himalayan broadleaf forest, a major habitat for the endangered red panda (Williams 2003).

Dominant forest species and composition of forest changes with elevation, for instance *Quercus* sp. in lower temperate forest (1,700-2,400 m a.s.l.), *Quercus* sp., *Rhododendron* sp., and *Acer* sp*., Pinus* sp. in upper temperate forest (2,400-2,800 m a.s.l.), *Rhododendron* sp*., Betula* sp., and *Acer* sp. in subalpine forest (around 3,000 m a.s.l.), and shrubby rhododendron species and junipers in the alpine zone (Dombremez, 1976, as cited in (Jackson 1994)). Grazing is prevalent above 2,500 m a.s.l., impacting the forest area with over-grazing (Regmi 2008), and has been listed as a major threat for biodiversity conservation (Shrestha et al. 2008).

A camera trap study was conducted to inventory the medium to large sized mammalian fauna in the region between December 2017 and June 2018, encompassing two seasons: winter (December 2017-February 2018) and spring (March-June 2018). The whole study area (Figure 5.1) was considered as a single block. The area above 2,000 m altitude was first selected by geoprocessing in ArcGIS 10.2. Then, we imposed uniform grid cells of 2 km x 2 km throughout the selected area. This resulted in 211 grids, of which only 60 grids were sampled based on habitat type and accessibility. During field sampling, we omitted private forest areas and difficult rocky mountain cliffs and steep-mountain slopes because of inaccessibility. Within a selected grid, active trails, and major areas of interest to wildlife, containing water sources, denning areas, major passes along mountain ridges, and mineral licks, were chosen for the installation site of the camera traps.

We used 63 passive infrared camera trap units (51 Bushnell® TROPHY® Cam HD camera trap units from Bushnell Outdoor Products, USA and 12 units of Strike Force Elite camera traps, Model BTC-5HDE from Browning®, Australia). The location and altitude of each site were recorded using a Gramin eTrex® 10 and Rino®120 handheld GPS.

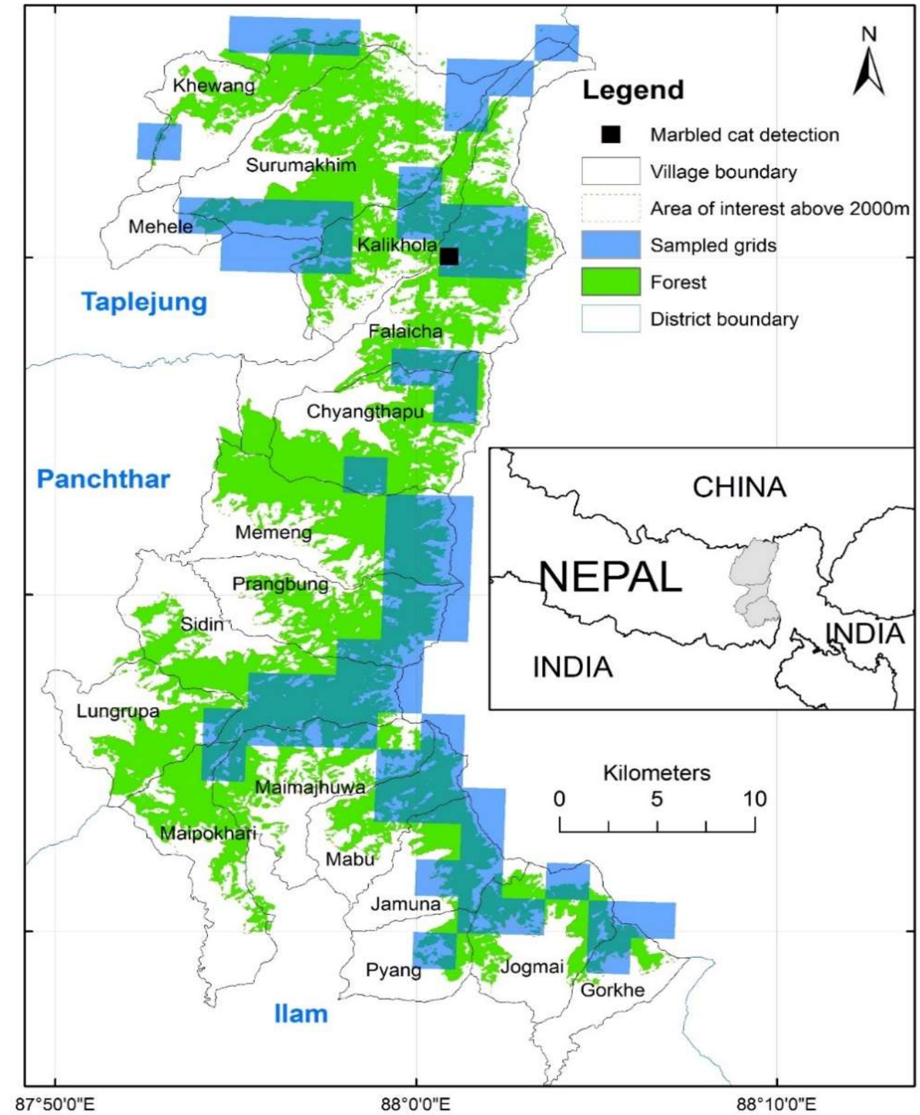

Figure 5.1: A map of the study area in eastern Nepal showing sampled grids in blue and location of the marbled cat.

On average, the cameras were left in the forests for 28 trap days. The minimum trap days for a camera was 14 days while 78 days was the maximum. The camera traps were installed at 107 locations. Cameras were secured to available tree trunks. The sensor height of the cameras installed above ground level was 32 cm on average. Every 24 hours was considered as one camera trap day for this study. The photographs were sorted manually and also with help of Microsoft Access-based Camera Base 1.7 (Tobler 2015). The species from the photographs were identified with the help of the references from Sanderson and Watson (2011), Johnsingh and Manjrekar (2012), and Menon (2014) and as well as consultation with experts and Forest Guardians from local villages who assisted with installing the camera traps. Photographs that were taken more than 30 minutes apart from each other were considered as independent events (Di Bitetti et al. 2006; Silver et al. 2004).

5.4 Results and Discussions

Overall, there were 3,014 trap days (1,377 in winter and 1,646 in spring) from the 107 camera stations (53 in winter and 55 in spring) that collected 5,176 photographs of 17 medium-large sized mammal species. Of interest were three photos of a small felid (two whole body and one tail-only photo from its right flank) in a single event from a location ID W33 (27° 20' 2.22" N, 88° 0' 55.08" E; datum WGS84), (elevation: 2,750 m a.s.l.; aspect west; slope: steep, details on table 5.1) on dusk at 17:44 hr on 21 January 2018 (Figure 5.1). During the successive spring season (March - June) we surveyed the area where the marbled cat was detected intensively and systematically with seven monitoring stations. This resulted in 233 more camera days but with no more images of the marbled cat. One of the cameras was installed in previously trapped locations for a further 35 days.

The recorded location of cat was near Tham Chok (a temporary shed for *dokpa*) from Phalaicha village in Panchthar District. The photos of the small-felid were markedly different from other small cat images captured by other cameras in the area. Long, fluffy, and erect tail, black edged large blotches on a flank and solid spots on the limbs were consistent with a marbled cat (confirmed by Igor Khorozyan, Jim Sanderson, Karan Shah, Kashmira Kakati, and Rinjan Shrestha). The camera trap images also matched (Figure 5.2) with published photos of the species (Nowell and Jackson 1996; Dhendup et al. 2016; Sethy et al. 2017). The marbled cat images clearly differed from the other felid species observed in this study, i.e. asiatic golden cat, common leopard, and leopard cat. The confirmation of the presence of marbled cat at this site supports C. MacDougal's suggestion (Nowell and Jackson 1996) about the presence of marbled cat in Nepal despite the lack of clear evidence about the origin of the cat's skin.

The habitat of the Tham Chok area is upper-temperate broadleaved forest (Figure 5.3). The vegetation in the area is dominated by *Lithocarpus pachyphylla, Castanopsis hysterix, Rhododendron grande, Taxus wallichiana, Lyonia ovalifolia, Alnus nepalensis* with thickets of *Yushania maling.* The recorded site is close to the Iwa River, which originates from Timbung Lake at 4,200 m a.s.l. The ridge is just above the confluence of Iwa and Barne Rivers, which stretch towards the border with India, approximately 4 km away. The area is a summer grazing pasture for cows and goats and also a winter grazing pasture for *dzomu* (domestic yak-cow hybrids), supporting around 150 livestock over the winter. The eastern part of the Tham Chok is a largely rocky area with dwarf trees, probably recovering from a historical forest fire. A large area of primary forest in the Iwa River valley was burnt by a forest fire, presumably caused by incidental poachers, approximately 3.5 decades ago (pers. comm. K. Bhandari 2018). That forest fire caused huge damage to the local fauna and flora at that time. The habitat area is crisscrossed by human and livestock trails. A human trail was 50 m away from the camera trap station that recorded the marbled cat. The elevation record of the species in this study at 2,750 m a.s.l. is higher than the elevation limit of the species for Nepal (< 2,500m) indicated by Baral and Shah (2008). Despite a heavy presence of humans and livestock in the area, there is some pristine primary forest dominated by *Lithocarpus pachyphylla, Castanopsis hysterix, Rhododendron* sp., in the eastern portion of the area, approximately 2.5 kilometres away. That primary forest could be a refuge habitat for many wildlife species, including small and medium sized-felids.

The other mammal and bird species captured at the same camera trap were the northern red muntjac *Muntiacus vaginalis*, orange-bellied Himalayan squirrel *Dremomys lokria*, and the Kalij pheasant *Lophura leucomelanos.* Similarly, leopard cat, yellow-throated marten and wild boar were recorded in spring season. The photo capture rate for that camera was highest for the muntjac followed by the squirrel in winter. The main prey present in the area, the orange-bellied squirrels (Nowell and Jackson 1996) were also found to be strongly diurnal of habit in this study (Figure 5.4). Our images also support that marbled cat was primarily diurnal in the habit (Figure 5.2) as do many other records around the world (Table 5.2). A nearby camera trap, approximately 1 km away, only captured the photographs of *dzomus*, indicating the pressure of livestock in the area.

Marbled cat appeared to have very low capture rate throughout their range. The reason behind the low rate of the capture of the species could be due to the rareness of the species itself (Nowell and Jackson 1996; Azlan and Sharma 2006; Cheyne and Macdonald 2010). A failure to record the marbled cat during the spring season, despite intensive sampling of locations may also indicate the rareness of the species in our study area or that we missed them because all of our cameras were based on the ground and they can be arboreal in nature. Azlan and Sharma (2006) also reported a very low abundance of marbled cat (only one photo) and suggested that the cat could be rare and/or mostly arboreal. Cheyne and Macdonald (2010), in Sabangau peat-swamp forest, Indonesian Borneo, had succeeded in trapping a single image of this cat over 15-months, which further suggests the rarity of this species in natural habitat. Camera trap images of the marbled cat and the leopard cat were shown to nine *dokpa* (herders) in the first week of October 2018 to see if they had sighted the cat in their area. Four of *dokpa* reported sighting the marbled cat but all of them named it as a *chari bagh* (leopard cat). They understood them as a poultry pest that sometimes prey on goats. They had knowledge of the use of marbled cat skin and bones but their knowledge is more based on the leopard cat.

Table 5.1: Camera trap location details where marbled cat was photographed in lower Kangchenjunga region, eastern Nepal.

Parameter	Value
Location ID/Name of Location	W33/Tham Chok
Long/Lat	27° 20' 2.22" N, 88° 0' 55.08" E
Elevation	2,750 m
Total number of photos	3
No. of Independent events	1
Duration of camera placement	7-22 Jan 2018 (15 days)
Date, time, & temp of marbled cat photo	2018-01-21, 17h 44, & 5° C
Habitat type	Upper-temperate mixed-broadleaved forest
Site aspect	West
Slope	Steep
Camera sensor height from ground	50 cm
Distance to nearest human settlement	1.4 km
Distance to nearest cattle herding station	0.4 km
Distance to forest edge	320 m
Distance to permanent water source	1 km
Distance to nearest forest in Sikkim, India	4 km
Distance to nearest trail for human & livestock	50 m
Other mammal species captured at the same camera	Orange-bellied Himalayan squirrel & Northern red muntjac
Birds species captured in the same camera	Kalij-pheasant
Species captured by the camera trap in same location in spring season	Leopard cat, Red muntjac, Yellow-throated marten and Wild boar

Figure 5.2: An image of the marbled cat from the camera trap (Sonam Tashi Lama-Lincoln University/Red Panda Network).

The records of a marbled cat skull by Pocock (1939) from adjoining Darjeeling, India, and one skin record originating from Sikkim, indicate that the cats were present in the region decades ago. This was also supported by the recent camera trapped marbled cat in Sikkim, adjoining and contiguous to our study area (pers. comm. P. S. Ghose 2018). This is consistent with the specimen collected by Hodgson from Nepal and the listing this species in Nepal-list by Horsfield (1856).

Hodgson was not allowed to travel outside of Kathmandu Valley during his stay in Nepal, but he recruited a team of hunters and trappers to collect specimen for him (Datta and Inskipp 2004). He also did the same during his time (1845-1858) in Darjeeling, India (Hunter 1896) and his four helpers (bird and animal shooters, collector and taxidermist) travelled to eastern Nepal from October through December 1948 with Sir Josheph Dalton Hooker (Hooker 1889). Due to the requests from the Lamas of Buddhists monasteries in Darjeeling and Sikkim not to shoot or even fish in their surrounding (Hunter 1896), this might have limited the collection. On the other hand, some local ethnic people in eastern Nepal worked as licenced hunters for four generations to British India to hunt and trap birds and mammals for collections (pers. comm. S. B. Rai 2017).

The forest area where the marbled cat was detected has been naturally restored as a secondary forest after a forest fire that occurred nearly 3.5 decades ago. The slash-and-burn agriculture system was practised in the adjoining areas for many years until around 1998 (pers. comm. K. Bhandari 2018). The ongoing restoration of the secondary forests supports healthy biodiversity, including the top predators, and provides opportunities for combining forest regeneration and sustainable rural livelihoods by local people (Chazdon 2008). After banning grazing in the forest and removing mobile pastoralism in Sikkim in 1998 and Singhalila in 1992, the pressure of livestock has concentrated into the study area (Thomas 2014). The current number of livestock (cow, buffalo, yak, sheep and goat) in surrounding villages (Phalaicha and Kalikhola only) is 6,472 (MoLD 2017), of which at least 50% of them are grazing freely in nearby forests.

Figure 5.3: The landscape and forests of the marbled cat capture area. The cat was photographed at far right. (Sonam Tashi Lama-Lincoln University/Red Panda Network).

Small cats have been little studied in Nepal (Thapa 2014). The conflict of humans and marbled cat throughout its range appears to be low. It is not clear whether the low level of knowledge about the marbled cat throughout its range is due to rarity or to its solitary and cryptic nature as a species (Sunquist and Sunquist 2017). In this context of limited knowledge on its ecology, distribution, and status on a global level (Ross et al. 2016), we stress further research on its ecological aspects and appeal for conservation programmes outside the protected areas of Nepal. Further, we recommend more camera trapping surveys in forested areas of the mid-hills of Nepal because most of the large-scale and dedicated camera trapping studies to date have been confined to the Terai region or high mountain regions of Nepal. We expect to find the presence of marbled cat in KCA, Makalu Barun National Park, and forested areas in the mid-hills, east of CNP. As the coverage of forested areas by camera trapping survey in western Nepal is very low and only limited to the protected areas, we cannot definitively conclude its absence from that region.

Based on a single presence location recorded in this study, it would be impractical to conclude anything about habitat characteristics for the marbled cat in Nepal. Limited information on population ecology, interactions with other sympatric felids, as well as how the species responds with the growing anthropogenic interactions in human-dominated landscapes, does not allow for an effective conservation plan. Nevertheless, record of this species within a human-dominated landscape underpins the need of wildlife-friendly conservation measures to secure human-wildlife coexistence. Potential habitat identification following habitat zonation measures will help limit human activities outside the core habitat thus minimizing threat to some extent. However, an in-depth study on habitat

Figure 5.4: The Orange-bellied Himalayan squirrel, a probable primary prey of marbled cat is abundant in the study area. This individual was captured by the same camera trap.

characteristics, diet, distribution, movement, and activity pattern will further guide in formulating effective conservation plan targeting this species.

Table 5.2: Published camera trap photo records of the marbled cat in range-countries sorted by date of trap.

S.N.	When	GPS Location	Altitude (m)	Time/Period	Habitat	Where	Country	Source	Remarks
1	1993	NA	NA	NA	NA	Khao Yai Wildlife Sanctuary	Thailand	(Jackson 1997)	live
2	1994	NA	NA	NA	NA	Huai Kha Khaeng Wildlife Sanctuary	Thailand	(Nowell & Jackson 1996)	First-ever camera trap photo in range countries
3	2000-03-04	25° 35' 11" N 94° 57' 23" E	1,970	18h 33	NA	Saramati Taung	Myanmar	(Zaw et al. 2014)	
4	2000-11-11	21° 21' 11" N 92° 26' 29" E	530	02h 14	NA	Rakhine Yoma (Paletwa)	Myanmar	(Zaw et al. 2014)	
5	2001-06-29	5° 6' 41.990" S 104° 8' 52.969" E	1,089	07h 41-12h 35	Tropical peat-swamp forest	Bukit Barisan Selatan National Park, Sumatra	Indonesia	(Cheyne & Macdonald 2010; Wibisono & McCarthy 2010)	a pair & one was melanistic
6	mid-2002	5° 14' N 118° 30' E	NA	NA	Selectively logged forest	Tabin Wildlife Reserve, Sabah	Malaysia	(Yasuda, Matsubayashi, Rustam, Sukor, & Bakar 2007)	
7	2003-12-17	26° 39' 44" N 96° 35' 39" E	230	08h 06	NA	Hukaung Valley	Myanmar	(Zaw et al. 2014)	
8	2004-05-02	27° 40' 42" N 98° 12' 07" E	2,620	11h 10	NA	Hkakaborazi	Myanmar	(Zaw et al. 2014)	
9	2008-02-26	17° 52' 29.795" N 105° 13' 24.601" E	758	10h 46	NA	Nakai-Nam Theun National Protected Area	Lao PDR	(Coudrat et al. 2014)	
10	2009-08-19	2° 31' S 113° 90' E	NA	12h 55	Tropical peat-swamp forest	Sabangau Forest, Kalimantan	Indonesia	(Cheyne & Macdonald 2010)	
11	2009-09-05	NA	NA	23h 33	Tropical peat-swamp forest	Sabangau Forest, Kalimantan	Indonesia	(Cheyne & Macdonald 2010)	
12	2010-12-01	27° 4' 15.744" N 93° 46' 56.1" E	553	06h 40	Tropical forest	Pakke Tiger Reserve, Assam, Arunachal	India	(Lyngdoh, Selvan, Gopi, & Habib 2011)	
13	Nov 2010 – Feb 2011	NA	NA	NA	Tropical & Sub-tropical forest	Royal Manas National Park	Bhutan	(Tempa et al. 2013)	
14	Sep 2011 - Feb2012	NA	3,488-3,810	Day & night	Broad leaved and Mixed conifer forest	Jigme Dorji National Park	Bhutan	(Thinley, Morreale, Curtis, & Lassoie 2015)	highest altitude for the marbled cat so far
15	April 2012	12° 40' 13.2" N 106° 57' 31.4" E	NA	04h 49	mixed deciduous/semi-evergreen forest	Phnom Prich Wildlife Sanctuary	Cambodia	(Gray, Phan, Chanrattanak, & Sovanna 2014)	
16	2012-07-15	05° 11.850' N 116° 57.720' E	159	05h 52	Logged forest	Imbak Canyon Conservation Area, Sabah	Malaysia	(Bernard, Brodie, Giordano, Ahmad, & Sinun 2013)	
17	2012-08-13	05° 02.070' N 117° 02.511' E	489	06h 20	Primary forest	Imbak Canyon Conservation Area, Sabah	Malaysia	(Bernard et al. 2013)	
18	March 2013	24° 11' 17", N 91° 44' 56" E	68	Daytime	NA	Srimangal sub-district	Bangladesh	(Khan 2015)	live
19	2014-10-07	NA	NA	08h 12	Tropical Forest	Gaoligongshan National Nature Reserve	Yunnan, China	(KFBG 2015)	first camera trap photo in China
20	2014-12-14	NA	NA	17h 10	NA	Medog and Chayu County	Tibet, China	(Guokr 2015)	first camera trap photo from Tibet
21	2015-12-22	23° 39' 19.48" N 92° 22' 05.90" E	586	10h 36	Tropical mixed forest	Dampa Tiger Reserve, Mizoram	India	(Sethy, Gouda, & Chauhan 2017)	
22	2015-12-27	23° 39' 19.48" N 92° 22' 05.90" E	586	16h 51	Tropical mixed forest	Dampa Tiger Reserve, Mizoram	India	(Sethy et al. 2017)	
23	2016-01-24	NA	1,455	13h 29	Bamboo-dominated forest	Virachey National Park, Phnom Haling	Cambodia	(Edward 2016)	
24	NA	NA	NA	Daytime	NA	Chittagong Hill Tract	Bangladesh	(Hance 2016)	First-ever camera trap photo in Bangladesh
25	2017-01-21	27° 20' 2.22" N 88° 0' 55.08" E	2,750	17h 44	Upper-temperate mixed-broadleaved forest	Panchthar District	Nepal	This study	
26	Recent	-	-	-	-	Sikkim	India	Pers. comm. P. S. Ghose 2018	first-ever camera trap

	photo in Sikkim, India

NA – Not available

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(Note that I have left the references for this chapter here as was submitted to the journal and is in different referencing format).

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Chapter 6

Thesis summary

This study was able to detect 17 medium and large sized terrestrial mammals in the study area and the total number of mammal species recorded was 23, including the small mammals. The study conducted during the winter and spring season of 2018, was able to provide the seasonal activity patterns of the terrestrial mammals through their photographic records. The relative abundance index provided the composition of the medium and large sized terrestrial mammals in the study area.

The camera trap study on red panda was pioneering in its nature for Nepal. This study showed that the red panda can be captured by both ground and arboreal camera traps if the selection of sites for camera placement is well considered. The arboreal camera traps were found to be more effective in capturing panda photos and independent events of red panda. Employing both camera trap positions in monitoring red panda would provide better understanding of their activity pattern and behaviour. Regarding the quality of the photographs and capture of the facial marks by camera traps, the arboreal camera would be good for identifying individual animal.

6.1 Limitations of the present study

There were several limitations to this study that I have summarised here.

- The limited number of camera traps did not allowed us to cover the whole study area at one time. This might have affected the collected data as different sites were monitored at different parts of the winter under different weather events. The available personnel to set camera traps in field was also limited due to the financial constraints. This did not allow us to set up the available cameras all at once. It usually took one to two weeks to set up all of the available camera traps in field.

- The camera trapping efforts in all the vegetation zones were not uniform, with less trapping days in alpine region of the study area due to weather condition and remote location.

- Some species may have been hibernating or denning during the winter season in the study area. Camera trapping in the monsoon season might detect such species and provide an estimate for their actual abundance in the area.

- For the arboreal camera trapping, health and safety requires a lot of preparation before leaving for the field. Sampling in the demanded a specialised climbing technique to access the tree canopies, which limited where the cameras could be placed.

- False triggering of the camera traps in tree canopies is difficult to limit regardless of removing branches and leaves in front of cameras. In seasons of greater activity this may limit the number of relevant images that can be collected on one SD card.

- There was a loss of data due to the mishandling of the camera traps and memory cards in the field and a pair of camera traps were stolen in one location, which forced us to remove all the camera traps before the planned date of camera trapping.

- The logistics of transportation of camera traps to our remote field sites required considerable time.

6.2 Future research

Based on the results of this study, there are several paths forward for continuing this research.

- A camera trapping study to measure the diversity of small mammals in this area is also necessary. The height of the camera traps could be lowered for capturing small mammals.

- Study on the activity patterns of the mammals in the area employing more camera traps in a single period of study would provide more robust and reliable results. A study covering all the seasons of a year would better reflect the diversity in the area and the activity patterns for these species.

- In a future camera trapping study, the camera traps should be placed in denser habitat areas to capture the arboreal felids, like clouded leopard.

- An ecological impact of the likely extirpation of the golden jackal from the area should be done.

- The impact of untied and free ranging domestic dogs to wild mammals should be measured.

- The photographs of red panda captured from the dedicated survey could be utilised for identification of an individual animal for estimating populations from their the coat patterns and facial markings (Shrestha et al. 2015).

- The monitoring of a latrine site use pattern by red panda through arboreal cameras should be done. This study was only conducted for few months or during the winter season, thus monitoring of red panda throughout the year is would be beneficial to obtain more robust data on their activity patterns and behaviours. Despite that, it would be best to avoid using arboreal camera traps during the breeding season. At that time only the ground-based camera trapping should be used, particularly to observe the outings of re panda cubs from their dens. This will also help in monitoring the threats of roaming domestic dogs and other human anthropogenic threats in the red panda habitat area.

- It would also be effective to study the use pattern of different heights of a tree by red pandas. This would allow the identification of the level of canopy that is important for their denning, roosting, and feeding.
- Trails of using lures (odour, food) to increase the detection probability of some of the target species would be beneficial.

Appendix A: Checklist of birds captured by the camera traps in the study area

Table A. 1 The checklist of birds captured by the camera traps in the study area during winter and spring seasons. Among them, one species is near threatened and one is vulnerable in the nationally threatened species list.

*Status refers to status in the proposed PIT Protected Forest: am = altitudinal migrant, sv = summer visitor, wv = winter visitor, r = resident, and pm = passage migrant. ? indicates uncertainty about the status Adapted from Inskip et al. (2018).
**Nationally Threatened Species: VU = Vulnerable, EN = Endangered, CR = Critically Endangered, DD = Data Deficient, and NT = Near Threatened.
x indicates biome restricted species.

S.N.	English Name	Scientific Name	Nepali Name	Status*	Biome-restricted species	Nationally Threatened species**
	GALLIFORMES					
	Phasianidae					
1	Kalij Pheasant	*Laphura leucomelanos*	कालिज	am		
2	Hill Partridge	*Arborophila turqueola*	पिउरा	am	x	
3	Satyr Tragopan	*Tragopan satyra*	मुनाल	am	x	VU
4	Blood Phesant	*Ithaginis cruentus*	चिलिमे			
5	Himalayan Monal	*Lophophorus impejanus*	डाँफे	am		NT
	PASSERIFORMES					
	Leiotrichidae					

6	Spotted Laughingthrush	*Garrulax ocellatus*	मुदाँले तोरीगाँडा	r	x
7	Chestnut-crowned Laughingthrush	*Garrulax erythrocephalus*	कटुसटाउके तोरीगाँडा	am	
8	Black-faced Laughingthrush	*Garrulax affinis*	कानटाटे तोरीगाँडा	r	x
9	Striated Laughingthrush	*Garrulax striatus*	कल्की तोरीगाँडा	r	x
10	Scaly Laughingthrush	*Trochalopteron subunicolor*	कल्ले तोरीगाँडा	r	x
11	Scaly Thrush	*Zoothera dauma*	गोब्रे चाचर		
12	Hoary-throated Barwing	*Sibia nipalensis*	वनचाहर	r	x
	Sylviidae				
13	White-browed Fulvetta	*Fulvetta vinipectus*	पितनयन फूलबुट्टा	am	x
14	Great Parrotbill	*Conostoma aemodium*	चाँदे बाँदरचरी		
	Pellorneidae				
15	Rufous-winged Fulvetta	*Alcippe castaneceps*	कटुसटाउके फूलबुट्टा	am	
	Sittidae				
16	White-tailed Nuthatch	*Sitta Himalayensis*	पहाडी मट्टा	am	x
	Muscicapidae				
17	White-browed Bush-robin	*Tarsiger indicus*	सेतोआँखीभौ रबिन	am	x
18	White-tailed Robin	*Myimela leucura*	सेतोपुच्छ्रे रबिन	sv	
19	Snowy-browed Flycatcher	*Ficedula hyperythra*	सेतोआँखीभौ अर्जुनक	sv	
20	Blue Whistling Thrush	*Myophonus caeruleus*	कल्चौंडे	r	

21	Plain-backed Thrush	*Zoothera mollissima*	सादाढाडे चाचर	am	
22	Rufous-gorgetted Flycatcher	*Ficedula strophiata*	सेतोटिके अर्जुनक	am	x
23	White-capped Water-redstart	*Chaimarroornis leucocephalus*	सेतोटाउके जलखंजरी	sv?	
24	Indian Blue Robin	*Lusciania brunnea*	नीलो रबिन	sv	x
	Phylloscopidae				
25	Ashy-throated Warbler	*Phylloscopus maculipennis*	फुस्रोकन्ठे फिस्टो	am	x
	Fringillidae				
26	Pink-browed Rosefinch	*Carpodacus rodochroa*	रातो झिबी तितु		
27	Spot-winged Rosefinch	*Carpodacus rodopeplus*	पंखथोप्ले तितु		
28	Dark-breasted Rosefinch	*Procarduelis nipalensis*	नेपाल तितु	wv	x
29	White-winged Grosbeak	*Mycerobas carnipes*	धूपी महाठूँड		
	Corvidae				
30	Yellow-billed Blue-magpie	*Urocissa flavirostris*	सुनठूँडे लामपुच्छ्रे	r	x
	Turdidae				
31	White-collared Blackbird	*Turdus albocinctus*	कंठे चाँचर	am	x
32	Grey-winged Blackbird	*Turdus boulboul*	मदना चाँचर	am	
	Prunellidae				
33	Maroon-backed Accentor	*Prunella immaculata*	पाण्डुनयनी लेकचरी	wv	x
	Timaliidae				
34	Streak-breasted Scimitar Babbler	*Pomatorhinus ruficollis*	छातीधर्से पाल्कोटे	r	
	Zosteropidae				

35	Stripe-throated Yuhina	*Yuhina gularis*	थुपलकल्की जुरेचरा	am	x
	COLUMBIFORMES				
	Columbidae				
36	Oriental Turtle Dove	*Streptopelia orientalis*	तामे ढुकुर	am	
	PICIFORMES				
	Picidae				
37	Darjeeling Woodpecker	*Dendrocopos darjellensis*	दार्जीलींग काष्ठकूट	r	x

Appendix B: Photos of all mammal species captured during the camera trap survey

Carnivora

Figure B.1.1: A tree climbing red panda captured by an arboreal camera trap.

Figure B.1.2: A red panda descending from a tree early morning.

Figure B.1.3: This red panda was captured by an arboreal camera trap installed on a tree trunk spent two hours and eighteen minutes in front of that camera trap. The red panda was sleeping most of the time.

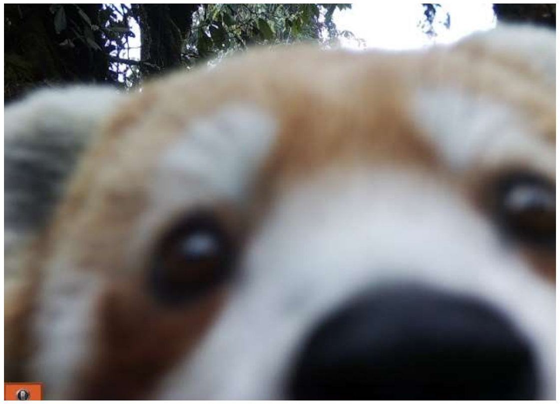

Figure B.1.4. A red panda selfie.

Figure B.1.5: Leopard *Panthera pardus*.

Figure B.1.6: Asiatic golden cat *Catopuma temminckii*.

Figure B.1.7: Marbled cat *Pardofelis marmorata*.

Figure B.1.8: Leopard cat *Prionailurus bengalensis*.

B.1.9: Himalayan black bear *Ursus thibetanus*.

Figure B.1.10: Red Fox *Vulpes Vulpes.*

Figure B.1.11: Yellow-throated marten *Martes flavigula.*

Figure B.1.12: Mountain weasel *Mustela altaica.*

Figure B.1.13: Siberian weasel *Mustela sibirica.*

Figure B1.1.14: Yellow-bellied weasel *Mustela kathiah* captured by an arboreal camera trap.

Figure B.1.15: Himalayan palm civet *Paguma larvata.*

Figure B.1.16: Spotted linsang *Prionodon pardicolor*.

Cetartiodactyla

Figure B.2.1: Northern red muntjac *Muntiacus vaginalis.*

Figure B.2.2: Himalayan serow *Capricornis thar*.

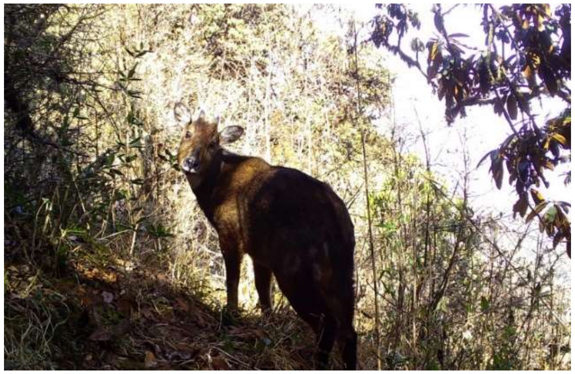

Figure B.2.3: Himalayan goral *Naemorhedus goral*.

Figure B.2.4: Wild boar *Sus scrofa*.

Primates

Figure B.3.1: Assam macaque *Macaca assamensis*.

Rodentia

Figure B.4.1: Hiamalayan crestless porcupine *Hystrix brachyura*.

Figure B.4.2: Orange-bellied Himalayan squirrel *Dremomys lokriah*.

Figure B.4.3: Flying squirrel.

Figure B.4.4: Rat *Rattus* sp.

Logomorpha

Figure B.5.1: Pika *Ocotona* sp.

Appendix C: Photos of nationally threatened birds captured during the camera trapping survey

Galliformes

Figure C.1.1: Himalyan monal *Lophophorus impejanus*.

Figure C.1.2: Satyr tragopan *Tragopan satyra*.

Appendix D: Comparative images from arboreal camera traps

Figure D.1: The same red panda with distinguishable facial patterns captured by an arboreal camera trap in a location on two different dates (11 Feb and 25 Feb 2018).

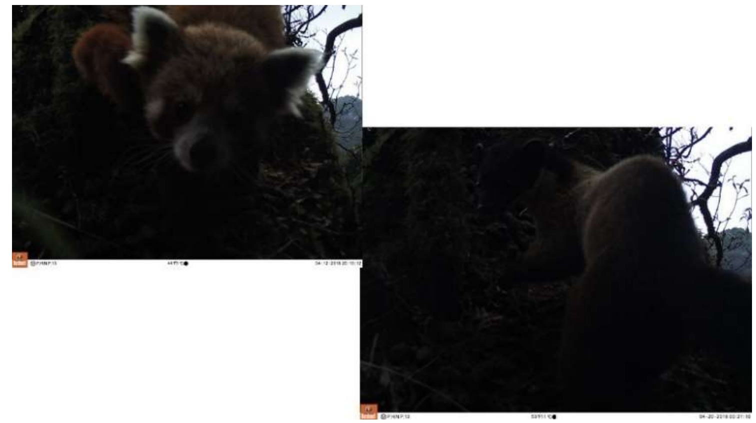

Figure D.2: The possible predator of the red panda, Yellow-throated marten visiting a site in a tree that was frequently used by a red panda.

Appendix E: List of mammals captured by arboreal camera traps

Table E.1 List of mammal species captured by arboreal camera traps during the study period

Order/Family	Species[1]	Nepali Name[2]	Common Name	IUCN Status ver 3.1[a]	Nepal Status[3]
Carnivora					
Ailuridae	*Ailurus fulgens* (F. G. Cuiver, 1825)	*Habre, Punde Kundo*	Red panda	EN	EN
Mustelidae	*Martes flavigula* (Boddaert, 1758)	*Malsanpro*	Yellow-throated marten	LC	LC
	Mustela sibirica (Pallas, 1773)	*Siberian malsanpro*	Siberian weasel	LC	LC
	Mustela kathiah (Hodgson, 1835)	*Pitodar malsapro*	Yellow-bellied weasel	LC	DD
Viverridae	*Paguma larvata* (C. E. H. Smith, 1827)	*Kala*	Himalayan palm civet	LC	LC
Cetartiodactyla					
Cervidae	*Muntiacus vaginalis* (Zimmermann, 1780)	*Mriga*	Northern red muntjac	LC	VU
Primates					
Cercopithecidae	*Macaca assamensis* (M'Clelland, 1840)	*Aasami Bandar*	Assam macaque	NT	VU
Rodentia					

Sciuridae		*Rajpankhi*	Flying squirrel		
	Dremomys lokriah (Hodgson, 1836)	*Lokharke*	Orange-bellied Himalayan squirrel	LC	LC
Muridae	*Rattus* sp.	*Musa*	Rat		
Chiroptera					
Unidentified family	Bat sp.	*Chamero*	Bat		

[1]Taxonomic information of the mammalian species was accessed from Integrated Taxonomic Information System (ITIS) https://www.itis.gov/ as of 5 November 2018
[2]Nepali names were accessed from Baral and Shah (2008)
[a]EN: endangered; VU: vulnerable; NT: near threatened; LC: Least concern IUCN (2018)
[3]EN: endangered; VU: vulnerable; NT: near threatened; LC: Least concern; DD: data deficit.
IUCN Status ver. 3.1 as of 5 November 2018 from IUCN (2018) https://www.iucnredlist.org/
Nepal's red list status was extracted from Jnawali et al. (2011)
- Not applicable

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