DISTRIBUTION AND HABITAT USE OF RED PANDA (*Ailurus fulgens* CUVIER 1825) IN EASTERN NEPAL

BY

KAMAL KANDEL

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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DECLARATION

I Kamal Kandel hereby declare that the dissertation entitled **"Distribution and Habitat Use of Red Panda (*Ailurus fulgens* Cuvier 1825) in Eastern Nepal"** submitted to **Central Department of Zoology, Tribhuvan University** in Partial Fulfillment of the requirements for the Award of the **Master's Degree in Zoology** is a record of original and independent research work of its kind done by me and has not been submitted anywhere else for securing any academic degree. The findings stated in this dissertation are based on my own field works.

Date:

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RECOMMENDATION

It is my pleasure to mention that Mr. Kamal Kandel has carried out the dissertation entitled **"Distribution and Habitat Use of Red Panda (*Ailurus fulgens* Cuvier 1825) in Eastern Nepal"** under my supervision and guidance. This is the candidate's original work, which brings out important findings essential for biodiversity conservation in remote mountain region of Nepal. To the best of my knowledge, this dissertation has not been submitted for any other degree in any institution. I recommend that the dissertation be accepted for the partial fulfillment of the requirement of the **Master's Degree in Zoology** specializing in **Ecology**.

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APPROVAL

On the recommendation of supervisor Dr. Mukesh Kumar Chalise, Associate Professor of this department, this dissertation submitted by Mr. Kamal Kandel entitled **"Distribution and Habitat Use of Red Panda (*Ailurus fulgens* Cuvier 1825) in Eastern Nepal"** is approved for further examinations.

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ACCEPTANCE

This dissertation submitted by Mr. Kamal Kandel entitled **"Distribution and Habitat Use of Red Panda (*Ailurus fulgens* Cuvier 1825) in Eastern Nepal"** has been accepted as a partial fulfillment of **Master's Degree in Zoology** specializing in **Ecology**.

EXPERT COMMITTEE

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ABSTRACT

Red panda (*Ailurus fulgens*), a habitat specialist of Himalaya, were studied in Hangetham and Choyatar CF of Eastern Nepal. Altogether 10 transects summing to 18.7km were established along with 187 systematic and 28 sign plots comprising of 3 units ($10x10m^2$, $5x5m^2$ and $1x1m^2$). The fecal groups of red panda was found in 6.91% (n=13) of the systematic plots. The evidences were scattered from 2200m to 2900m asl in the study area with index of sign abundance in between altitudinal range of 2700-2900m asl (42.85/ha / 12.14/km). Red panda used trees as defecation sites (substrate) most frequently (44.05%) followed by rock (33.33%), forest floor (11.90%), fallen logs (9.52%) and cut stumps (1.20%) and differed significantly (χ^2 = 53.97, df=4, $p<0.05$). Availability of water source (mean=40.17±6.53m) differed significantly within its different categories (χ^2= 1.1.83, df=4, $p<0.05$), as 61.90% of fecal groups were found 0-25m away from sign centered plots. Red panda used steep slopes of 40^0 more often (76.19%) and northern faces. More fecal groups (36.90% and 46.43%) were found in 26-50% range of overstory crown canopy and understory bamboo cover. Mann-Whitney *U* test showed six habitat variables (slope, bamboo cover, bamboo height, bamboo diameter, proportion of dry bamboo shoots, and shrub density) differed significantly ($P<0.05$) between systematic and red panda sign plots and therefore are important elements of the red panda habitat. Three individuals of red panda were sighted in two sighting incidents during the study. A carcass of red panda was also found which was supposed to be predated upon by Mountain Hawk Eagle (*Spizaetus nipalensis*).

Inadequate species level awareness in the local community about red panda's ecological importance and high dependency on its habitat for people's livelihood is creating its survival pressure. For effective conservation of this species, it requires not only the considerations of red panda but also the wellbeing of dependent local community. Furthermore, it is needed the intense research on its spatial distribution, specific habitat requirements and threats on broader scale.

Keywords: *Red Panda, Community Forest, Eastern Nepal, distribution, conservation*

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ABBREVIATIONS AND ACRONYMS

asl	– Above Sea Level
CF	– Community Forest
CFUGs	– Community Forest User Groups
CITES	– Convention on International Trade for Endangered Species of Flora and Fauna
Cm	– Centimeter
DBH	– Diameter at Breast Height
GIS	– Geographical Information System
GoN	– Government of Nepal
GPS	– Global Positioning System
Ha	– Hector
IUCN	– The World Conservation Union
IVI	– Important Value Index
Kg	– Kilogram
Km	– Kilometer
m	– Meter
m^2	– Square meter
mm	– Milimeter
NTFP	– Non-Timber forest product
^oc	– Degree centigrade
Pers. comm.	– Personal Communication
Pers. obs.	– Personal Observation
RPN-Nepal	– Red Panda Network-Nepal
SPSS	– Statistical Program for Social Science
VDC	– Village Development Committee

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CHAPTER-1 INTRODUCTION

1.1 Background

Mammalian diversity is high in the Nepal Himalaya largely because of its multiple zoo-geographic origins. Its location at the juncture of two major realms, Palaeartic in north and Oriental in south, places it in an ecotone represented by flora and fauna from both and mixing with indigenous ones makes the country rich from all levels of its biodiversity. Varied climatic zones supporting a diverse array of ecosystems, a wide altitudinal range, and the vast stretch of the Himalayan range itself are other contributing factors. Nepal offers an unusual opportunity to study vast arrays of fauna and flora of different origin and hence coined as “Zoo-geographical labyrinth” (Shrestha 2003).

The distribution of rare mammals in the Nepal Himalaya is homogeneous and suffers from some distributional gap which is still indicated by floristic distribution (Shrestha 2003). It is a matter of biological inquiry that why such floristic and faunistic discontinuities exists. Furthermore, the habitat destruction and fragmentation due to high dependency on natural resources of the ever-growing human population, the survival of many mammalian species of the Himalayas is at an immediate risk. The destruction of forest ecosystems is especially tragic when it results in the extinction of species that have small geographic ranges and are adapted to a narrow range of habitats. In Nepal Himalaya, the possibility of such extinction is high for the red panda (Yonzon 1989). The red panda is an indicator of habitat quality, and is an umbrella species for temperate and subalpine forest in the Eastern Himalaya (Yonzon et al 1991) and is also charismatic and thus a flagship species (WWF and ICIMOD 2001).

Community near red panda habitat mainly subsists on animal husbandry, peripheral agriculture and small trade relying heavily on natural resources in Nepal Himalayas. Year round grazing pressure on the fragile mountain environment and increased demands for timber and firewood are continuing the degradation of red panda habitat especially outside the protected area system of Nepal as 62% out of 912 km^2 of the probable red panda habitat remains outside protected areas (Yonzon et al 1997). Habitat connectivity and contiguity is especially important in the steep, tall Himalayan range, because many ecological processes and phenomenon depend on or are related to the altitudinal changes. So, there is need to conserve blocks of intact habitat capable of supporting viable populations of red panda and associated ecological processes (WWF and ICIMOD 2001).

The red panda has its patchy distribution in temperate and alpine region of Nepal Himalaya from east to Namlung Valley of Mugu district (Roberts and Gittleman 1984) in the west with narrow altitudinal range of distribution may be due to their specialized food item and behavior.

Studies of red panda in the wild have been conducted in Nepal (Yonzon 1989, Yonzon et al 1997, Mahato 2003,2004, Williams 2004, Kandel 2008, Sharma 2008, Karki 2009), in India (Pradhan et al 2001a, 2001b) and in China (Johnson et al 1988, Wei et al1999a,1999b, Wei et al 2000) and more needs to be known about the pattern of distribution, population status, preferred habitats, availability and quality of such habitats in relation to food, cover and safety.

This study has focused on the distribution of red pandas in eastern Nepal. In addition, the study attempts to assess the relative sign abundance and the habitat use of red panda. This is accomplished by assessing the index of sign abundance and analysis of habitat parameters.

1.2 Research Problem Statement

Red panda is legally protected by Government of Nepal under Schedule I (section 10) of National parks and wildlife conservation Act 2029 (1973). It was listed under "Endangered" category of IUCN since 1994. It is now enlisted under "Vulnerable" category of IUCN red data list (IUCN 2008) and in Appendix I as an endangered and protected animal, that subjects to the international trade restriction under CITES. Despite its recognition as a species of global importance, a flagship and indicator species of eastern Himalayan broadleaf and coniferous forests, continued habitat loss and fragmentation threatens the survival of red panda and make it one of the most endangered mammal species on earth. To protect red panda and its habitat effectively, some basic information regarding its distribution, abundance and habitat use is needed. The lack of such reliable scientific information is creating difficulty in prioritizing conservation actions and is one of the most pressing problem in the conservation of red panda in Nepal Himalayas (Yonzon et al 1997). Similarly, Glatston (1994) recommends carrying out status and distribution surveys of red panda for its conservation. Lack of adequate information regarding status and distribution of such endangered species may lead to local extinction owing to no conservation efforts. Despite the extensive protected area network of Nepal covering nearly about 20% of the total area, more than 62% of the red panda potential habitat remains outside the protected areas which may have higher risk due to human pressure (Yonzon et al 1997), still few research works that were carried out on red panda were concentrated on the protected areas only (Yonzon 1989, Mahato 2003, 2004).

Considering these facts, more needs to be known about the pattern of distribution, population status, preferred habitats, availability and quality of such habitats in relation to food, cover and safety outside the protected areas.

1.3 Objectives

The main objective of the study is to collect the baseline information on red panda in eastern Nepal. The specific objectives are:

Objective I: To assess the distribution of red panda in Ilam

Objective II: To find out the relative sign abundance of red panda in the study area

Objective III: To assess the habitat use of red panda in Ilam

1.4 Research question

Is there a relationship between the red panda presence to the elevation, aspect, slope, canopy cover, bamboo density and availability of source of water?

1.5 Limitation of the study

Political instability of eastern Nepal, due to strike and Bandha as well as financial constraints, seasonal data couldn’t be gathered which is the greatest limitation of this study.

1.6 Organization of the dissertation and research approach

There are seven chapters organized to answer the research question mentioned above, they are:

Chapter 1 describes the general background and problem about the red panda and its habitat. Subsequently, research assumptions, statement of the research problem, research objectives and research questions are defined. From it, one can understand why the topic is proposed and overall aims of the dissertation.

Chapter 2 presents a comprehensive description of literature available related to the species and topic.

Chapter 3 introduces study area, materials and method. This chapter presents the reader what kind of materials and methods are applied in this research and how they are implemented, including data collection, data processing and data analysis. A comprehensive description about the study site is elaborated such as location, climate condition, drainage system, terrain, vegetation and fauna, bamboo, population and human activities.

Chapter 4 presents analysis and results of the dissertation that is divided into different sub-chapters. Each sub-chapter incorporates their respective outcomes presented in different forms such as Tables and Figures.

Chapter 5 presents a general discussion of the results of chapter 4 and be compared with available literatures on the related field.

Chapter 6 presents the conclusions of study related to the objectives. Inferences drawn from chapter 4 and 5 are presented briefly.

Chapter 7 presents the recommendations for further follow up study and conservation of species as a whole in Nepal.

CHAPTER-2 LITERATURE REVIEW

2.1 History of evolution of red panda

Red panda appeared until the Pleistocene (Schaller et al.1985), though a red panda like animal, *Parailurus* occurred during the Pliocene in Europe (Thenius 1979 cited in Yonzon 1989), North America (Tedford and Gustafson 1977), and Japan (Sasagawa et al 2003). *Parailurus* is believed to be a close relative of the extant red panda, *Ailurus fulgens* (Wang 1997, Peigne et al 2005). The specimen found in Japan might be phylogenetically closer to *Ailurus* than European and American *Parailurus* because of its proportion (Sasagawa et al 2003). Fossils of the modern red panda occurred in the mid-Pleistocene in Yunnan along with *Ailuropoda melanoleuca* and *Stegodon orientalis*, but intermediate forms between *Parailurus* and *Ailurus* are unknown (Roberts and Gittleman 1984). Thus, the ancestral stock of the red panda may have stretched across northern parts of the eastern and western hemispheres (MacClintock 1988 in Yonzon 1989). The small size and diminished range of extant red panda may represent a specialized early offshoot of Ailurinae that survived Pleistocene glaciation in mountain refugia of southern China (Pen 1962 in Roberts and Gittleman 1984). Perhaps the tectonic plate movement and uplift of the Himalayas during the Pleistocene brought moist climax forest habitat to the mountain, which was gradually colonized by the red panda. Later, a series of disjuncture populations formed (Schaller et al 1985) because the Himalayan Mountains developed both physical and ecological barriers such as deep gorges and rivers (Rau 1974 in Yonzon 1989).

2.2 Phylogeny of red panda

Red panda (*Ailurus*) is the only extant representative of its lineage. Until very recently, no direct ancestors of the red panda were known. The familial-level phylogenetic position of *Ailurus* and its fossil relative *Parailurus* is quite controversial. Geoffroy-Saint-Hilaire and Cuvier 1825 first described the red panda as closely resembling a raccoon (Procyonid), although they gave it the name Ailurus based on its superficial likeness to that of the domestic cat (Flynn et al 2000). They have been variously placed in the Procyonidae (Wayne et al 1989; Wang, 1997) mainly by the similarities in their molars, the Ursidae (Wozencraft, 1989), with *Ailuropoda* in the Ailuropodidae (Corbet and Hill, 1986), and in their own family, the

Ailuridae (Eisenberg 1981 cited in Glatston, 1994; Roberts and Gittleman, 1984; Ginsburg et al 1997). Based on available data, it appears that mtDNA analyses recover Mephitidae, and Ailuridae as sister (Flynn et al 2000), nuclear DNA supports Ailuridae as branching after Mephitidae (Fulton and Strobeck 2006), and a combination of the two yields a 'compromised' position of Ailuridae as the most basal Musteloid lineage (Flynn et al 2005). However, the relatively poor fossil record of the red panda clade (compared to other mustelida clades) prevents the recognition of late Oligocene – early Miocene ancestors.

Another well-known extinct relative of *Ailurus fulgens* is the genus *Simocyon* known from late Miocene of Shannixi, China (Wang 1997) which is considered to fall in subfamily Simocyoninae in family Ailuridae (Peigene et al 2005).

2.3 Red panda and giant panda

Red and giant pandas, in the order carnivore, share a number of anatomical and ecological characteristics. Both pandas represent not only monotypic genera, but also are sole representatives of the subfamilies Ailuropodinae and Ailurinae. Affinities of two pandas to each other are so strong that the giant panda could be described as a small panda like animal that has grown large with secondarily evolved bear like physical and behavioral attributes (Schaller et al 1985). Secondly, they have specialized on bamboo diets and share the same bamboo species in regions of sympatry (Schaller et al 1985, Johnson et al 1988, Reid et al 1991). Both the giant panda (*Ailuropoda melanoleuca*) and the red panda (*Ailurus fulgens*) possess a 'false-thumb' actually an enlarged radial sesamoid bone, which contributes to the gripping action of the hand to handle bamboo stems effectively (Anton et al 2006).

Both the pandas retain the short, relatively simple digestive tracts typical of other carnivores and cannot digest cellulose (Dierenfeld et al 1982, Schaller et al 1985, Warnell et al 1989, Wei et al 1999a). Finally, both pandas are confronted by the environmental pressures such as habitat loss, population isolation and human interference (Glaston 1994, Schaller et al 1985, Wei et al 1999b). Studies have shown, both pandas suffer high mortality in the wild, about 75% for cubs of giant pandas (Wei and Hu 1994) and 86% for cubs of red pandas in Nepal (Yonzon 1989). In addition, both have certain vocalizations, scent-marking techniques, and similar aspects of reproduction, diet, and foraging behavior (Schaller et al1985). Noticeably, the red panda differs from the giant panda by having a longer tail, smaller body size, cryptic coloration, and a dense mat of hair covering the soles of the feet. The diploid chromosome number in the red panda is 36, suggesting a closer affinity to the procyonids (38 diploid chromosomes) than to the giant (42 diploid chromosomes) and the bears (74 diploid chromosomes) (Ewer 1972 cited in Yonzon 1989).

2.4 Global distribution of red panda

The red panda *Ailurus fulgens,* Cuvier 1825 is distributed in the isolated high mountain ranges in Western China (Sichuan, Yunnan and Tibet Provinces) and the Himalayan mountain chains of Nepal, India, Bhutan and Burma with a disjunct population on the Meghalaya Plateau of north-eastern India (Choudhury 2001, Li et al 2005).

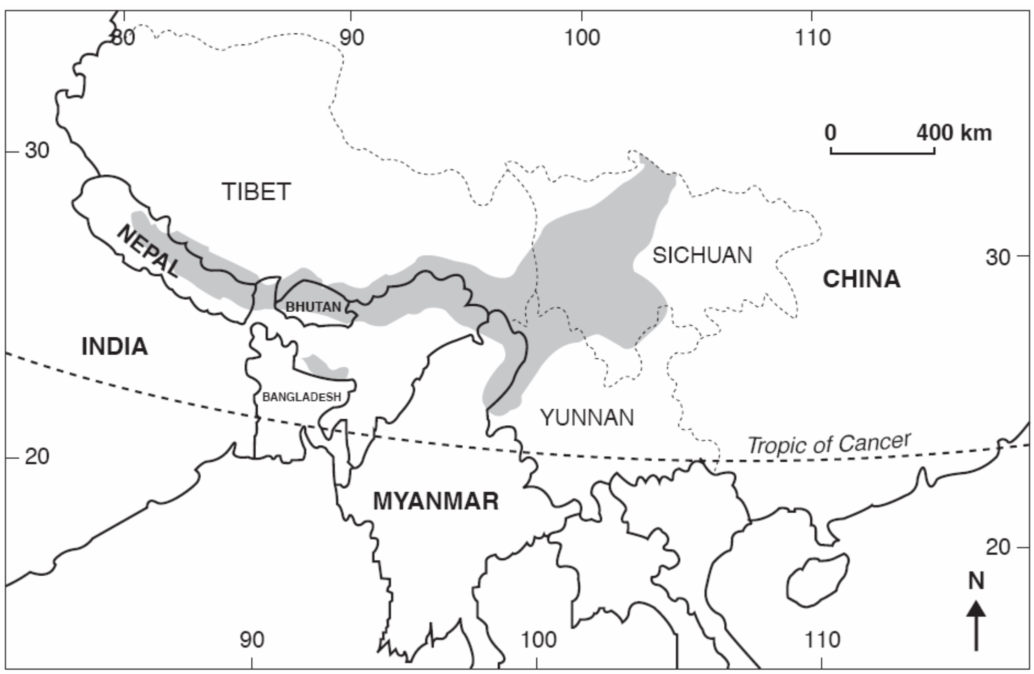


Figure 1: Global distribution (shaded area) of red panda (Source: Choudhary 2001)

Its westernmost occurrence is recorded in Mugu District, Western Nepal (82^0E), and easternmost in the Minshan Mountains and upper Min Valley of Sichuan Province, south-central China (104^0E) with a narrow extent of north-south distribution from 25^0N to 33^0N (Choudhury 1997). There are two sub-species of red panda based on morphology and distribution. Among them *Ailurus fulgens fulgens* is found in the Himalayan region including Nepal, India, Bhutan, Burma and China (North Eastern

Part of Tibet and Western Yunnan) and another sub-species called *Ailurus fulgens styani* is slightly larger and is found in south Western China in Sichuan, Yunnan Provinces. These two being isolated by the Nujiang River, which has been proposed as a bio-geographical barrier (Roberts and Gittleman 1984, Glatston 1994, Wei et al 1999b, Chalise 2001). The distribution is associated closely with temperate forests having bamboo-thicket understory between 2200m and 4800m (Roberts 1982a and Allen 1938 cited on Roberts and Gittleman 1984).

In Bhutan, red pandas have been reported from Jigme Dorji National Park, Thrumshinga National Park, Torsa National Park, Kulong Chu Wildlife Sanctuary and Black Mountain National Park. They are distributed on the large tracts of high altitude forests throughout northern Bhutan (Yonzon et al 1997). In Myanmar, the species is restricted to the northern mountains bordering India and China, especially Shan and areas of north of Putao (Rabinowitz and Khaing 1998). In India, the red pandas are confined to the north-east in Sikkim, Northern west Bengal and Arunachal Pradesh and isolated population in Meghalaya (Prater 1980, Choudhary 1997, Choudhary 2001 and Pradhan et al 2001a). In China, this species is confined to parts of Sichuan, Yunnan and Tibet (Wei et al 1999b).

2.5 Distribution of red panda in Nepal

Red panda are known to occur in high mountain range districts where fir with associated conifers occurs from east to the far west Nepal. The farthest west distribution of the red panda in Nepal has been reported in mid sixties from Jumla (Yonzon et al 1997). In addition, red panda also found in Rara National Park, Mugu district (Sharma 2008) which is considered as the westernmost limit of the distribution of red panda (Roberts and Gittleman 1984). Occurrence of red panda is confirmed from east Nepal to Baglung to Rukum (Yonzon et al 1997) including the following protected areas: Langtang National Park (Yonzon 1989), Annapurna Conservation Area (Shrestha and Ale 2001), Dhorpatan Hunting Reserve (Kandel 2008), Makalu Barun National Park (Jackson 1990), Manaslu Conservation Area (Choudhary 1992 cited in Yonzon et al 1997), Kangchenjunga Conservation Area (Yonzon 1996), Sagarmatha National Park (WWF 2003).

2.6 Population and status

On the basis of average density of one panda per 4.4 km^2, the estimated global population size of the Red Panda is 16,000- 20,000, within the total potential Red Panda habitat of 142,000 km^2 in 5 Red Panda range countries (Choudhury, 2001). In China, total population number estimated is about 6000-7000 decreased by as much as 40% over last 50 years (Wei et al 1999b). The estimated total population of red panda in Nepal is about 314 individuals based on the ecological density of one red panda per 2.9 km^2 within 912 km^2 potential habitat available (Yonzon et al 1997). In Langtang National park, 73 individuals of red panda were estimated based on the available habitat, isolated into 4 different isolated populations (Yonzon et al 1991). Similarly, more than 11 red pandas are present in Rara National Park within 31 km^2 (Sharma, 2008).

2.7 Physical characteristics

Red pandas are highly specialized species, with unique morphological and behavioural features, that have evolved to fulfill a niche as bamboo feeders. It averages 100 cm in length with its body being about 60 cm and tail about 40 cm long. Adult red panda in the wild weight about 4 kg while in captivity; they weigh 4 to 5 kg (Yonzon 1989, Shrestha 2003). The skull is robust, head is rounded, rostrum shortened and ears large, erect and pointed. The bushy tail is comparatively long and marked with about 12 alternating red and buff rings and not prehensile (Roberts and Gittleman 1984). Long, coarse guard hairs cover the entire body and the under coat is soft, dense and wooly. The face is predominantly white with reddish-brown 'tear' marks under the eyes. The fur on the upper side of its body is reddish-brown while ventrally it is glossy black. The legs are black and the soles of its feet are covered with dense white hairs. There is no sexual dimorphism in color or size between males and females. Front legs are angled inward, leading to its wadding walk. The feet are plantigrade (Roberts and Gittleman 1984).

2.8 Habitat and food habit

Red pandas are known to occur in temperate climates in mixed deciduous–coniferous forests of Himalayan ecosystems with the understory of bamboo and hollow trees with a dense canopy (Choudhory 2001) with the exception of Meghalaya where it is also found in tropical forests o(Choudhory 1997). Red panda prefers fir-jhapra forests between elevations of 2800m-3900m. However, within these forests red panda has several microhabitat requirements, a dense understory of fallen logs, fruiting shrubs and bamboo, bamboo stand height, tree canopy and close proximity to a water source (Yonzon 1989, Wei et al 1999a, Pradhan 1999a, Pradhan et al 2001a). Panda makes extensive use of north-facing slopes covered with fir *jhapra* forests (Yonzon et al 1991).

Very little is known about the feeding behaviour and nutritional requirements of red panda in the wild. The red panda is an unusual member of carnivore feeding mainly on bamboo leaves (Wei et al 1999a, Pradhan et al 2001b). In Singhalia National Park, 83-92% of diet consists of bamboo leaves complemented during the monsoon with bamboo shoots and fruits of various trees and shrubs (Pradhan et al 2001b). While in Langtang National Park, bamboo leaves constituted 54-100% of the food items in all seasons, comprising bamboo leaf only 68.5% (Yonzon 1989). In the Wolong Reserve (WR), China, *A. f. styani* diet was almost identical consisting of 93.7% bamboo leaves supplemented with bamboo shoots, and fruits of various shrubs (Reid et al1991). Occasionally, it feeds on insects, eggs, young birds and small rodents (Prater 1980) and expelled foetus and unfit neonates (Qin et al. 2007). In captivity, predation upon birds and rodents has also been reported, suggesting that they are somewhat opportunistic feeders. Seasonality of predatory behaviour has been suggested in red pandas, with 84% of incidents occurring during the breeding season (Bach 1998), mainly to provide additional energy and nutrients needed to support growing young. In wild, no significant carnivore diet is reported (Yonzon 1989, Pradhan et al 2001b, Karki 2009).

Physiologically, red pandas show some unique features that do not appear to class them strictly as omnivores, carnivores or herbivores. The tooth structure is very similar to that of an omnivore, whereas the ratio of body length to gut length is very similar to that of a small carnivore (Bleijenberg and Nijboer 1989). Although they consume a predominantly herbivorous diet, the gut lacks the adaptations that specialized herbivores posses to enable the efficient digestion of high fiber vegetation. This suggests that red pandas are unable to process herbivorous diet effectively and thus require a very large intake in order to receive sufficient levels of energy and nutrients.

2.8 Activity pattern and home range

Although red panda are found to be active during all times of the day, they are primarily crepuscular. In addition to dusk and dawn peaks, two another minor peaks also occur. They show the similar activity patterns in different seasons, probability of activities is highest in autumn and in winter due to food source i.e. patchily distributed fruits in autumn and mating in winter (Yonzon 1989). The red panda rests 63% of the day, exhibiting frequent activity periods interspersed with many rest periods lasting ≤2 hrs (Johshan et al 1988). Red panda shows sluggish movement to climb down and up the tree. They also produce vocalization response for dissociation frustration (Chalise 2009).

Home range sizes vary between 1.4-11.6 km^2. The average total home range was 5.12 km^2 for males and 2.37 km^2 for females. In Langtang National Park that means range of males is larger than those of females, especially during the winter, mating season. Home range overlapped between sexes and between males, but overlap seldom occurred between female's ranges. Habitat quality, especially the food availability and shelter influences mean home range size, the social system and, as a result, red panda density (Yonzon 1989).

2.9 Reproduction and lifespan

The reproductive biology of the red panda is not well known. There are indications that oestrous peaks in early winter (January - February), mate with one or more partner in a season and most litters are born between June and July. The gestation period is 114-156 days. Litter size ranges between one to four cubs, the mode being two. Before parturition the female begins to carry sticks, grass, leaves, and barks of trees to a suitable nest site which may be a hollow tree or a rock crevice. The young attain adult size at 1 year, sexually mature at 1.5 years, and stay with the mother for about a year, or until the arrival of next litter. The maximum life span of Red panda is 14 years but the average is 8-10 years in the wild (Roberts and Gittleman 1984).

CHAPTER: 3 METHODOLOGY

3.1 Study Area

The study area (N 27° 06′ 03.8″ E 87° 59′ 08.5″) encompasses the north eastern part of Ilam district south of Kanchenjunga Conservation Area. It lies in the western slope of the Singhalila ridge, adjacent to Singhalila National Park in Darjeeling India. This area forms a Nepalese part of Kanchenjunga-Singhalila complex on one of the five prioritized landscape of the eastern Himalayas, the Eastern Himalayan broadleaf and conifer global 200 eco-region (Olson and Dinerstein 1998) and Himalayan biodiversity hotspot (Myers et al 2000). The study area also covers the upper part of the upper Mai valley which is one of the Important Bird Area (Baral and Inskipp 2005). This area is important for red panda mainly because this provides a biological linkage between two protected red panda populations- Kanchenjunga Conservation Area in Nepal and Singhalila National Park in Darjeeling India.

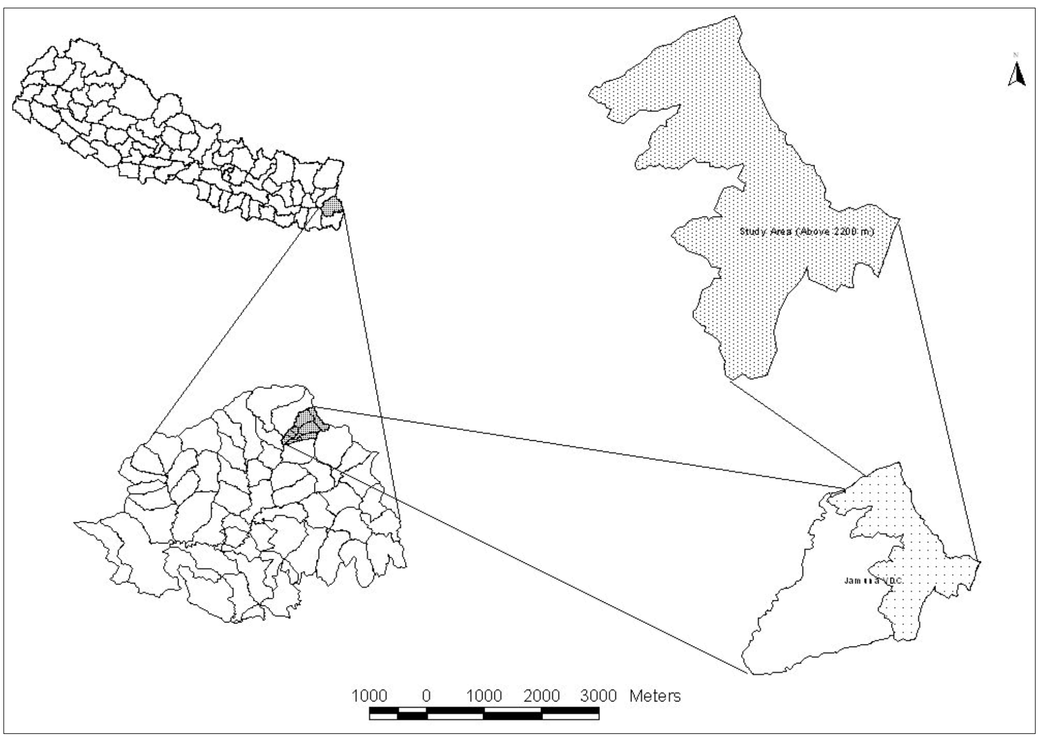


Figure 2: Location of study area in Eastern Nepal.

The Core study area, Choyatar and Hangetham CF lies under Jamuna VDC of Ilam district. It is the north south extension of the Singhalila range that forms the eastern political border of Nepal with India. Jaubari, Ingla, Gairibas and Kaiyakatta are the human settlements near to the core study area. Core study area is bounded by Singhalila ridge in the east, Dhuwa khola in the north, and Pyang and Jogmai VDC boundary in the south and lies above 2200m asl.

3.1.1 Climate

Eastern Nepal demonstrates the classic monsoonal pattern and has more in common with Darjeeling and Sikkim than with central or western Nepal. Darjeeling's average annual rainfall is 3100 mm with 518 mm of this outside of the monsoon months (Polunin and Stainton 2000). The monsoon wind causes rain from June through September. In the study area, from 2400m – 2800m, the temperature ranges from 7-17°C in the summer and 1-10°C in the winter, and, from 2800m – 3100m, average summer and winter temperatures are 7° and 1°C and varies with altitude. The mean average rainfall is 3500mm with an average humidity that ranges from 83-96% (Pradhan et al 2001a).

In the beginning of October the monsoonal rains taper off and cooler, clear days begin in the middle of the month. The days steadily become colder and Maple (*Acer sp.*), *Sorbus sp.*, and other deciduous hardwoods drop their leaves by the end of November or beginning of December. Misty damp days begin again and last until the first snow at the end of December. The irregular snows lasts well into March, with an occasional snow in April (Williams 2004).

3.1.2 Drainage System

The small streams occur in every part of the study area. The source of water comes from the southwest facing slope of the Singhalila ridge. Three main streams are Dhuwa Khola, Paha Khola and Ingla khola in the study area. They join finally flows to Mai Khola.

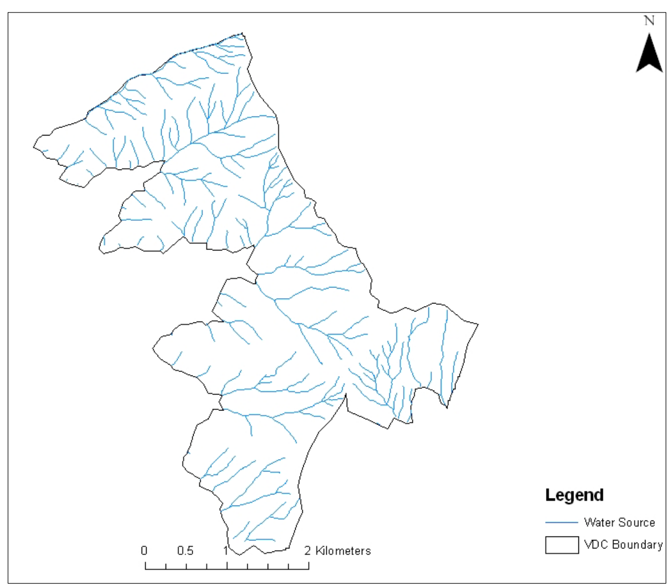


Figure 3: Map of drainage system in core study area

3.1.3 Terrain

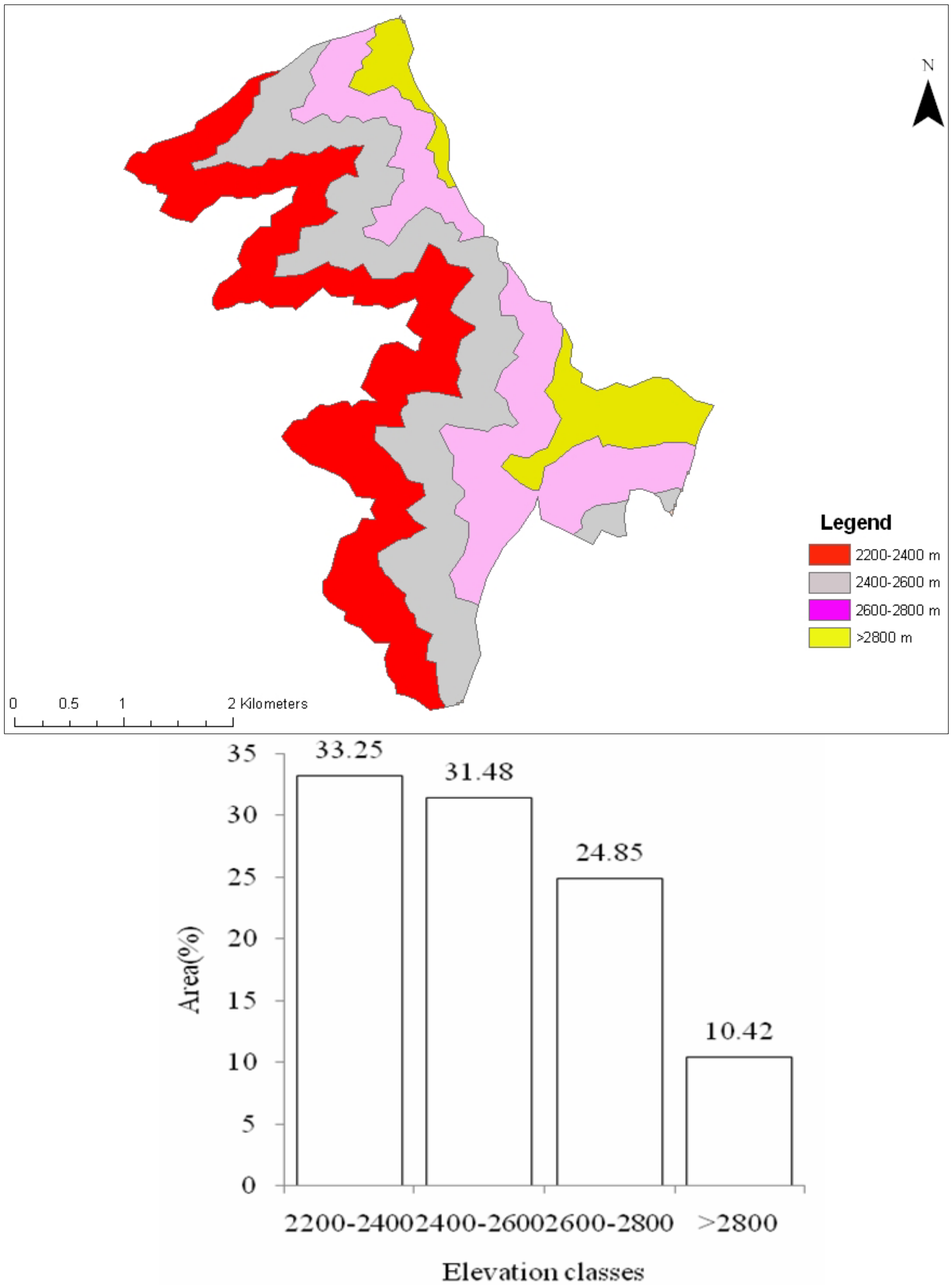
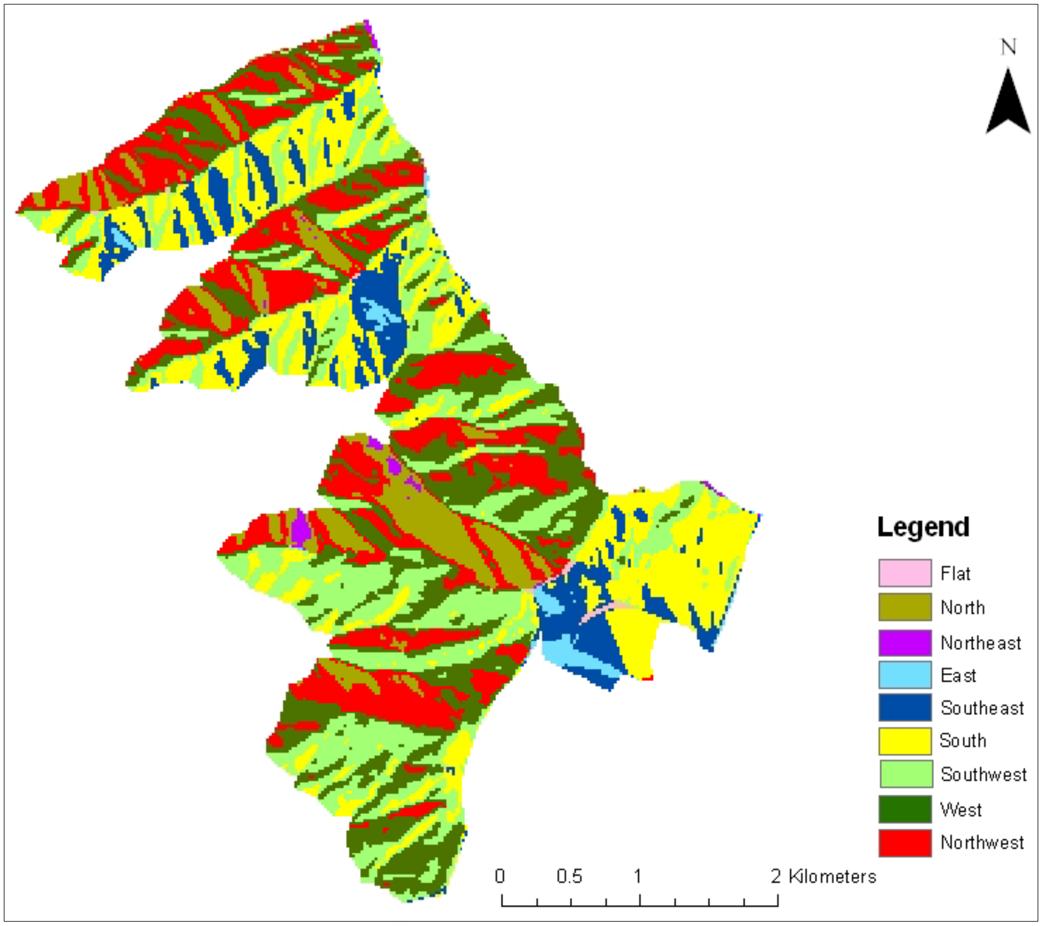


Figure 4: Elevation map and area proportion

The study area is located in the hinterland of the Singhalila range with an elevation range between 2200 to 2950 m asl. It is the rough mountain region. 33.25% of the area has a height between 2200-2400 m, 31.48% of the areas has a height between

2400-2600 m, 24.85% of the area has a height between 2600-2800 m and only 10.42% of the area has a height >2800 m (Figure 4).



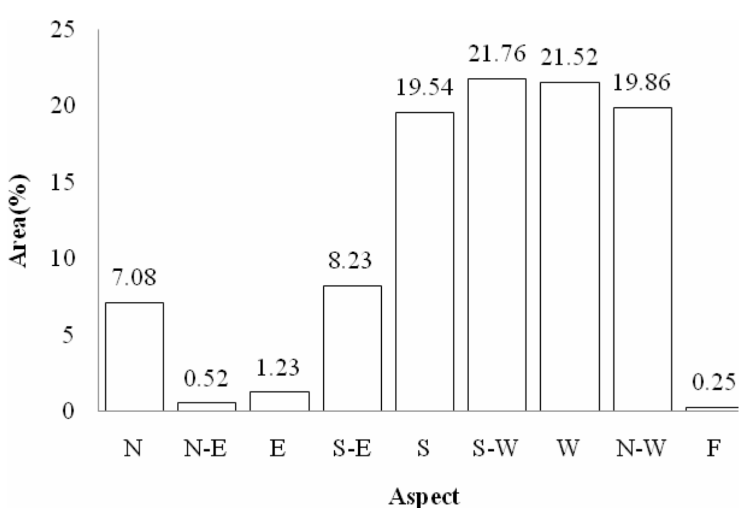
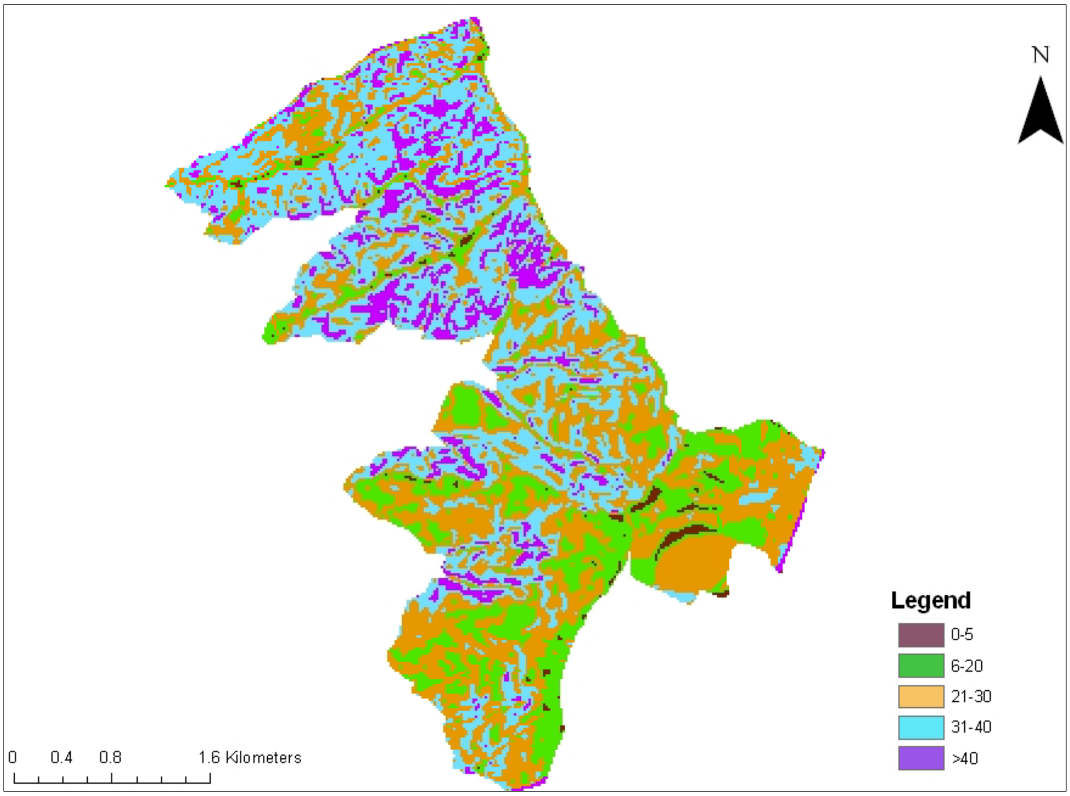


Figure 5: Aspect map and area proportion



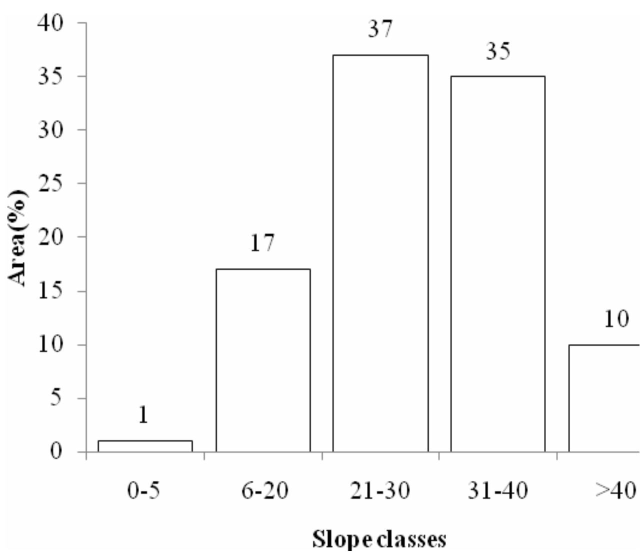


Figure 6: Slope map and area proportion

With respect to slope aspect, although study area is located in the west slope of Singhalila ridge, but the principle aspect still is southwest facing (21.76%), 21.52% area is west facing, 19.86% area northwest facing, 19.54% area is south facing while 7.60% area is north and northeast facing. The flat area is only 0.25% available in the study area (Figure 5). On slope gradient, five classes are shown in Figure 6. About 37 % area of the study area is 21-30 degree, the area of 35% is 31-40 degree, 17% area is 6-20 degree, 10% area greater than 40 degree and 1% area is 0-5 degree. The classification system is as followed by Wang (2003), and belongs to steep slope area, very steep slope area, moderate slope area, cliff area and gentle slope area respectively.

3.1.4 Flora of the study area

The combination of a strong moisture gradient, an elevational gradient, and different soil types influence the distribution of plant communities within the study area. The forests of the eastern Himalaya, represented by the eastern Himalayan broadleaf forest is among the most species-rich temperate forest in the world. They are dominated by evergreen broadleaf trees (eg. Quercus, Lauraceae) in the lower part (2000-2500m) and a mixture of evergreen conifers (eg. Tsuga, Taxus,) and winter-deciduous broadleaf species (eg Acer, Betula, Magnolia) in the upper part (2500-3000m). The drier, south-facing slopes support extensive stands of arboreal Rhododendron species that may co-occur with oak (*Quercus spp*.) or other ericaceous species such as *Lyonia ovalifolia*. These temperate forests support a rich epiphytic community, consisting of a variety of dicots, orchids, ferns and mosses. Bamboo (*Arundinaria spp*.) is also important as a component of the understory vegetation and as an early-successional ground cover following fire. Further upslope, subalpine conifer forests begin from about 3,000 meters and extend to 4,000 meters. In the eastern Himalayas, *Tsuga, Picea* or *Larix* dominate these forests between 3,000 meters to 3,500 meters and *Abies* dominates above 3,500 meters (WWF and ICIMOD 2001).

Four distinct clusters of vegetation communities corresponding to the vegetation communities in the altitude zones in Singhalila National Park. The vegetation zones are oak forest (2700-2800 m), broad-leaf deciduous forest (>2800-3100 m), broad-leaf coniferous forest (>3100-3300 m) and the coniferous forest (>3300-3600 m) (Pradhan et al 2001a).

3.1.5 Fauna of the study area

This region is the refuse to the species such as common leopard *Panthera pardus*, clouded leopard *Neofelis nebulosa*, Himalayan black bear *Solenarctos thibetanus*, leopard cat *Prionaulurus benghalensis*, and red panda *Ailurus fulgens*. Other common wild mammals sighted in the study area includes Himalayan serow *Nemorhaedus sumatraensis*, wild boar *Sus scrofa*, yellow throated martin *Martes flavigula*, porcupine *Hytrix indica*, assamese macaque *Macaca assamensis*, Himalayan langur *Semnopithecus entellus*, barking deer *Muntiacus muntijak*, black giant squirrel *Ratufa bicolor*, golden jackal *Canis aureus*, giant flying squirrel and Himalayan Civet.

Well over 254 bird species were recorded in the upper Mai valley in the study area (Robson et al 2008). Important bird species found in this region are restricted-ranged species: yellow vented warbler *Phylloscopus cantator*, rufous-thorated wren babbler *Spelaeornis caudatus*, spiny babbler *Tordoides nepalensis*, and hoary-throated barwing *Actinodura nipalensis* and very rare in Nepal: asian fairy bluebird *Irena puella*. Other bird species recorded are monal *Tragopan satyra*, pale headed woodpecker *Gecinulus grantia*, darjeeling woodpecker *Dendrocopos darjellensis*, yellow billed blue Macpie *Urocissa flavirostris*, himalayan griffon *Gyps himalayansis* (Baral and Inskipp 2005).

3.1.6 Population and human activities

According to CBS (2001), the total population of Jamuna VDC is 3632. In that VDC, the total numbers of households are 684 and the numbers of households containing cattle are 638. The main source of livelihood is agriculture and forest based economy. Commercial cultivation of NTFPs and Cardamom as well as raring cattle is the main economic activities in the study area.

3.2 Methods

3.2.1 Preliminary Survey

A preliminary survey of the study area was conducted from 16-27Aug 2008 to establish the knowledge on presence/absence of the red panda. After assessing the large area of north-eastern Ilam via ground truthing and information collected from locals, core study site (Hangetham and Choyatar CF) were selected for more intensive investigations of distribution, and habitat use of red panda.

3.2.2 Altitudinal Line Intercepts

Red panda usually leave a group of feces at feeding sites. Numbers in each group vary significantly. Number of feces in a single red panda defecation are usually 8-15, and 15-30 or sometimes >100 are found in repeatedly used sites, called latrines (Yonzon 1989, Raid et al 1991). Studies indicated that the longer the animals spent at the feeding sites, the more fecal groups were left. Therefore, a positive linear relationship exists between total time spent in feeding sites and number of feces deposited (Reid et al 1991). Because of the difficulty of observing activity of red panda as it lives in mountainous terrain covered by dense forests, the fecal deposition was an effective indicator of its distribution, abundance and microhabitat utilization (Wei et al 2000, Pradhan et al 2001a, Williams 2004).

Altitudinal line intercept method (Sutherland 1996) followed by Williams (2004) and Mahato (2004) was applied so as to record the red panda distribution. Horizontal transects from 2300m- 2900m following the contour lines perpendicular to the elevation gradient in each 100m altitudinal intervals were surveyed. Garmin Etrex GPS was used to geo-reference and Government of Nepal (GoN) 1:25,000 survey map as altitudinal guides. Silva compass and altimeter were also used. Whenever a fecal group was encountered, the point was geo-referenced with GPS. These points were then overlaid on the different image layers (altitude, water source etc.) with the help of ArcView 9.2 to generate a red panda distribution map for the core study area. For each individual sighting, information on number of animals, age and sex if possible, and activity were noted.

3.2.3 Relative sign Abundance

During the transect walk, when fecal groups were encountered, information including distance from the beginning point, number of groups and their age, substrate used, proximity to source of water, canopy cover, bamboo cover etc were recorded. Number of signs encountered/km of transect walk (Mahato 2004, Williams 2004) was used as an index to quantify the relative abundance in the study area.

3.2.4 Habitat Assessment

Habitat data were collected based on a field survey conducted during Dec 2008 to January 2009. GPS was used to record all the locations of all survey plots. Line transect sampling method was adopted to get many habitat types. The composition, structure of vegetation and the intensity and types of disturbances in the study area comprising of sites were assessed by placing 10x10 m^2 quadrates (n=187). These quadrates were placed at an interval of 100 m along altitudinal line intercepts starting from 2300m (Shrestha 1988, Pradhan et al 2001a, Williams 2004, Liu et al 2005), each of them containing 2 shrub plots (5x5m^2) and 4 bamboo plots (1x1m^2). Two 5x5m^2 shrub plots were arranged diagonally and four 1x1m^2 bamboo plots were arranged in four corners within 10x10m^2 plot.

The following detailed information were collected in each quadrate:

1. Terrain: (i.e. elevation, slope gradient, aspect and water source dispersion)
2. Tree layer (i.e. species, number, DBH, height, total canopy coverage, number of fallen logs and number of cut stumps within 10x10m^2 plot)
3. Shrub layer (i.e. species and number in two 5x5m^2 plots within 10x10m^2 plot)
4. Bamboo layer (i.e. average number of culms, average height, average diameter, total bamboo cover, proportion of new shoots, proportion of dried shoot in four 1x1m^2 bamboo plots within 10x10m^2 plot)
5. Red Panda signs (i.e. type of sign, number of sign groups, age of sign groups, substrate used within 10x10m^2 plot)

Whenever a fecal group was encountered, all the three independent units (10x10m^2, 5x5 m^2 and 1x1m^2 plots) were plotted and centered on the fecal location and termed as sign plot. All the above mentioned information were recorded and computed for statistical analysis. Nomenclature for plant species followed Polunin and Stainton (2000).

3.2.5 Analysis

All the data collected were arranged according to necessity and computed the required measurement.

The distribution pattern of red panda fecal groups was calculated by Variance to mean ratio (Odum 1971) which is based on the fact that in Poisson distribution, the variance (S^2) is equal to the mean.

If $S^2/X < 1$, Distribution is uniform

If $S^2/X = 1$, Distribution is random

If $S^2/X > 1$, Distribution is clumped

Measure of species importance was carried out following Krebs (1994)

$$\text{Density (P/ha)} = \frac{\text{Total number of individual of a species}}{\text{Total number of quadrates} \times \text{area of quadrate } (m^2)} \times 10{,}000$$

$$\text{Relative Density} (\%) = \frac{\text{Density of Species A}}{\text{Total density of all species}} x\ 100$$

$$\text{Frequency } (\%) = \frac{\text{Total number of plots in which species occures}}{\text{Total number of plot sampled}} x100$$

$$\text{Relative Frequency } (\%) = \frac{\text{Frequency of species}}{\text{Total frequency of all species}} x100$$

$$\text{Basal Area} = \pi d^2/4$$

Where, d = Diameter at breast height

$$\text{Relative Dominance } (\%) = \frac{\text{Basal area of a species}}{\text{Total area of all species}} x100$$

Important value index (IVI) = Relative Density + Relative Frequency + Relative Dominance

Index of Similarity = $\frac{2z}{x+y}$

Where, z = number of common species

x = number of species in quadrate A

y = number of species in quadrate B

The relative abundance of the tree species found in systematic and sign plots was measured in terms of Shannon-Wiener index (*H*) (Odum 1971).

$$H = -\sum_{i=1}^{s} Pi \ln Pi$$

Where, Pi= Proportion of individuals found in the i^{th} species

ln = Natural logarithm

S = Number of species in an area

The differences in the value of Shannon-Wiener index obtained for systematic plots and red panda sign plots was tested for significance using Student's *t* test (Jayaraman 2000).

$$t = \frac{|H1 - H2|}{\sqrt{Var(H1) + Var(H2)}}$$

Which without the absolute sign of numerator, follows Student's t distribution with v degrees of freedom where,

$$v = \frac{((Var\ (H1) + Var(H2))^2}{\frac{(Var\ (H1))^2}{N1} + \frac{(Var\ (H2))^2}{N2}}$$

And,

$$Var\ (H) = \frac{\left(\sum Pi(ln\ Pi)^2 - (\sum Pi \ln Pi)^2\right)}{N} + \frac{S-1}{2N^2}$$

Where, Var (H) = Variance in diversity

N1 and N2 = Number of individuals based on which H1 and H2 are calculated

S = Number of species in a sample

We performed a χ^2-test to test for the goodness of fit to gain insight into red panda use of different habitat parameters available.

$$\chi^2 = \sum[(observed\ frequency - expected\ frequency)^2/expected\ frequency]$$

Data were arranged in Microsoft Excel 2007 and analysis was performed using the statistical software package SPSS 13.00. A significance level of all tests was set at P= 0.05.

Description of variables used in the study

Variables	Description
Altitude	Altitude in m from ASL
Slope	From 0^0 to 90^0, defined as 5 categories: 1) 0-5^0 2) 6-20^0 3) 21-30^0 4) 31-40^0 5) >40^0
Slope Aspect	Aspect of each 100m^2 plot, defined as 8 categories: 1) North 2) Northeast 3) East 4) Southeast 5) South 6) Southwest 7) West 8) Northwest
Crown Canopy	Canopy of overstory in each 100m^2 plots, 7 categories: 1) <1% 2) 1-5% 3) 6-15% and 4) 16-25% 5) 26-50%% 6)51-75% 7)76-100%
Bamboo Cover	Bamboo Coverage in each 100m^2 plots, 7 categories: 1) <1% 2) 1-5% 3) 6-15% and 4) 16-25% 5) 26-50%% 6)51-75% 7)76-100%
Bamboo Density	Average number of culms in four 1x1m^2 bamboo plots (culms/m^2)
Bamboo Height	Average height of culms in four 1x1m^2 bamboo plots (in meter), 5 culms were measured randomly in each plot
Dried shoot proportion	Average proportion of old shoots in four 1x1m^2 bamboo plots (%)
New shoot Proportion	Average proportion of new shoots in four 1x1m^2 bamboo plots (%)
Tree Density	Average number of trees in 100m^2 plot
Tree Height	Average height of trees in 100m^2 plot
Basal Area	Average of total basal area covered by trees in 100m^2 plots
Shrub Density	Average number of shrubs in two 5x5m^2 plots
Fallen log Density	Number of fallen logs (diameter>10cm) in each 100m^2 plots
Cut stump Density	Number of cut stumps (diameter>10cm) in each 100m^2 plots
Water Source Dispersion	Estimated straight line distance from the sampling plot to the nearest water source; 5 categories: 1) <25m 2) 25-50m 3) 51-75m 4) 76-100m and 5) >100m
Disturbance factor	Disturbance factor; divided in 4 categories: 1) No 2) Low 3) Medium and 4) High

CHAPTER 4: RESULTS

4.1 Distribution of red panda

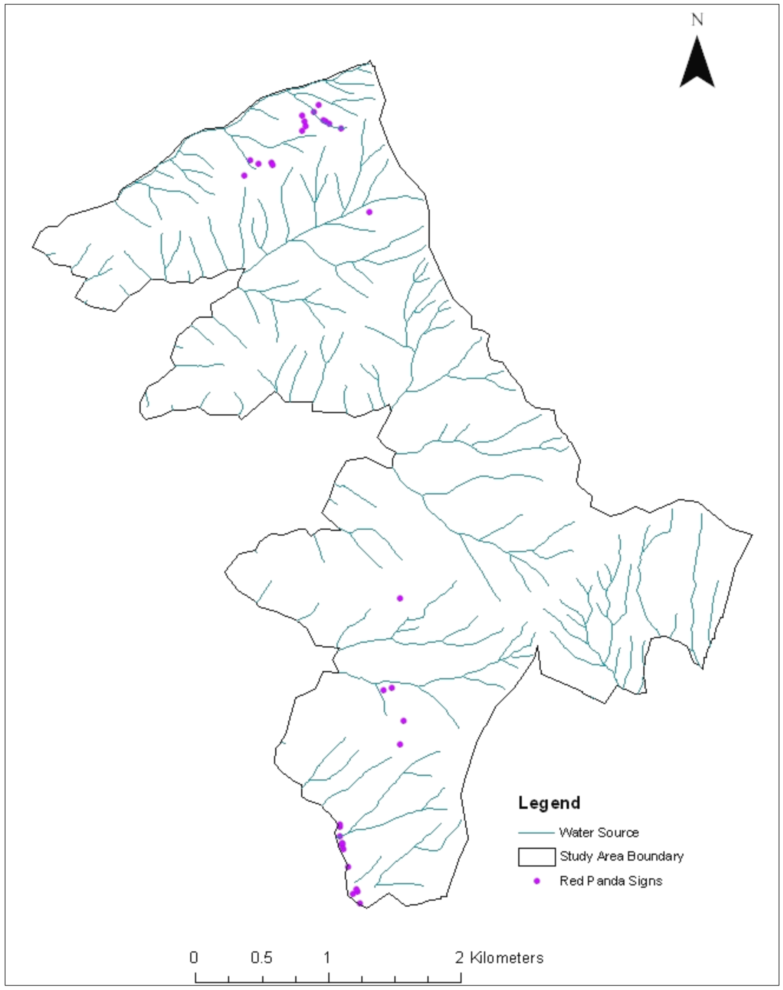


Figure 7: Distribuiton of red panda fecal groups in the core study area

The preliminary study and local information confirmed the presence of red panda in Maipokhari, Maimajhuwa, Mabu, Jamuna, Jogmai and Pyang VDCs of Ilam. Given that red pandas occur in all the core study area, infrequent sightings occurred during the field survey from October 2008 to January 2009. Three red pandas were encountered in two sighting incidents. Both encounters occurred during the transect walk in study area. Two red pandas were sighted together in Choyatar CF (2280m asl) at 12:15 hrs. These pandas were small and thought to be young adult. A fecal group with two different sized and aged pellets (probably of the cubs and mother) was also found nearby the area. These two individuals were observed for about 2.18hr. During this observation period, both the individuals were resting on a small branch of *Symplocus spp*. A single red panda was sighted in Choyatar CF near Dalsekholsa, just below Jaubari- a small transborder settlement at 2700m asl. It was observed for 2 minutes only. According to the local field guide, a group of 4 red pandas were seen in Khappare area of Choyatar Community forest just before two days (10^{th} January). Records of indirect evidences of red panda (fecal groups and paw prints) and direct observations of red panda were found between the elevations of 2200m to 2900m asl. The maximum elevation available in our study area was 2950m asl. As the variance is greater than arithmetic mean, the distribution pattern of red panda fecal groups is clumped in the study area ($S^2/\bar{X} = 6.17 > 1$, $\chi^2=1148.33$, $p<0.05$).

4.2 Relative sign abundance

Ten transects in total, summing 18.7 km in length, were laid in the study area and surveyed. Fecal groups were classified into different age classes as 48.81% very old, 44.05% old, 3.57% fresh and 3.57% very fresh. Average sign encounter rate for the whole study area was 4.45/km. In Hangetham CF, average fecal group encounter rate was 8.43/km and 2.10/km in Choyatar CF. Sign encounter rate was highest at 2900m in Hangetham CF (22.86/km) while in Choyatar CF at 2300m at the rate of 6.20/km. The details of sign encounter rate in different transects is shown in Table 1.

Table 1: Sign encounter rate in different transects in the study area

	# signs encountered/km transect walk							
Study areas	2300 m	2400 m	2500 m	2600 m	2700 m	2800 m	2900 m	Total
Choyatar CF	6.20	0	0.87	2.86	0	-	-	2.10
Hangetham CF	-	-	0	1.43	16.43	1.43	22.86	8.43
Total	6.20	0	0.54	2.28	6.76	1.43	22.86	4.45

Evidences of red panda were found in 6.95% of the total systematic plots (n=187). The density of the fecal groups in study area showed lowest density in the altitudinal range of 2300-2500m with 12.5/ha compared with 31.8/ha in range of >2500-2700m and 42.86/ha in >2700-2900m asl.

4.3 Habitat Use

4.3.1 Difference between habitat variables in red panda sign and systematic plots

Differences between the systematic plots and red panda sign plots using the 17 variables (altitude, slope, crown cover, bamboo cover, bamboo density, bamboo height, bamboo diameter, proportion of new bamboo shoots, proportion of old bamboo shoots, tree density, tree height, basal area coverage, shrub density, fallen log density, cut stem density, dispersion of water and disturbance factor) were studied.

Table 2: Quantitative difference between variables in red panda sign and systematic plots

	Mean± std. error			
Variables	**Systematic plot**	**Panda Sign Plot**	**Mann-Whitney (U)**	**P Value**
Altitude	2563.84±12.70	2635.71±47.20	2006.00	0.101
Slope	42.65±1.71	53.57±3.09	1786.00	0.017*
Crown cover	39.07±1.85	37.57±3.70	2445.50	0.911
Bamboo cover	37.25±2.30	50.36±4.53	1804.00	0.021*
Bamboo density	10.68±0.61	12.72±0.96	1780.00	0.129
Bamboo height	4.25 ±0.13	5.21±0.22	1323.50	0.004*
Bamboo diameter	1.47±0.03	1.70± 0.04	1199.50	0.001*
Prop. of _new shoots	19.65±0.91	21.06±1.91	1865.50	0.532
Prop. of dry shoots	25.98±1.14	16.30±2.36	1144.50	0.000*
Tree density	5.38±0.26	6.50±0.63	1982.50	0.088
Tree height	9.5±0.33	9.90 ±0.98	2319.50	0.830
Basal area	0.74±0.08	0.63±0.11	2329.50	0.643
Shrub density	7.84±0.44	5.02±0.63	1771.00	0.015*
Fallen log density	1.67±0.13	1.11±0.20	2131.00	0.219
Cut stem density	1.35±0.19	0.64±0.18	2382.50	0.710
Dispersion of water	58.29±4.11	40.36±6.29	2137.00	0.239
Disturbance	-	-	2055.00	0.131

* Significant at 0.05 level

The Mann-Whitney *U*-test detected that 6 (slope, bamboo cover, bamboo height, bamboo diameter, proportion of dry bamboo shoots, and shrub density) out of 17 variables differed significantly ($P<0.05$) between systematic and red panda sign plots (Table 2).

4.3.2 Species diversity, Dominance and Similarity index in systematic and sign plots

Shannon-Wiener index of diversity is found higher in systematic plot and differed significantly ($t = 2.45$, $P<0.05$). But, tree species are found more evenly distributed (Jacob's coefficient of evenness Table 3) in red panda sign plot than systematic plot. The Simpson's index of dominance showed dominance is shared by a large number of species and hence no prominent dominance in the study area, but index of dominance was found high in red panda sign plot (0.10) than in systematic plot (0.07). Sorensen's similarity index indicates high similarity in terms of vegetation between the systematic and sign plots, I_s = 70% (Table 3).

Table 3: Variations of $\bar{H}$, C, E and S in systematic and red panda sign plots

Plot type	Dom. Index (C)	Div. Index ($\bar{H}$)	Evenness (E)	Index of Similarity (S)
Red panda sign plot	0.103396	2.8388	0.834647	70%
Systematic Plot	0.06808	3.0648	0.796021	

4.3.3 Important Value Index of tree species in systematic and red panda sign plots

Tree species composition differs between red panda sign and systematic plots. 47 and 30 tree species are recorded in systematic and red panda sign plots respectively. Important plant species in the systematic plot based on the IVI value are *Lithocarpus pachyphylla* (62.88), *Symplocos theifolia* (29.14), *Litsea salicofolia* (22.09), *Rhododendron arboretum* (20.52), *Acer spp*. (16.66), *Machilus edulis* (14.17), *Quercus glauca* (13.08), and *Hymenodictyon excelsum* (11.03). In sign plots, important plants reported are *R. arboretum (*43.43), *L. pachyphylla* (39.65), *Magnolia campbelli (20.81), H. excelsum (*16.16), *Schefflera impressa* (14.84), *Michelia doltsopa* (11.22), *R. folconerii (10.07)* and *Sorbus cuspidata* (7.28). *S. impressa*, *R. folconerii*, *Sorbus cuspidata* are found to be more important plant species for red panda as their important value is high in red panda sign plots in comparison to systematic plot (Appendix: I &II)

4.3.4 Substrate used by red panda for defecation

The different substrate used by the red panda for defecation were trees (44.05%), forest floor (11.90%), fallen logs (9.52%), rock (33.33%), and stumps (1.20%). Trees were the most preferred site for defecation (χ^2=53.97, df=4, p<0.05). In Choyatar community forest, red panda used forest floor (32%) and fallen logs (32%) more than trees (24%) for defecation. No sign was found on log in Hangetham Community Forest (Table 4). Both of the red panda sightings were made on tree (*Symplocus spp. and Lithocarpus spp*.). Fecal groups were found on 10 species of trees namely *Lithocarpus spp* (29.73%), *Schefflera impressa* (18.92%), *Acer spp*. (16.22%), *Rhododendron arboreum*. (10.81%), *Castonopsis spp*. (5.40%), *Hymenodictyon excelsum* (5.40%), *Michelia doltsopa* (5.40%), Pamale (2.70%), *Quercus glauca* (2.70%) and *Betula utilis* (2.70%).

Table 4: Use of different substrates for defecation by the red panda in the study area

	Substrates				
Study sites	Tree	Forest floor	Rock	Log	Stump
	(% used)				
Choyatar CF	24	32	8	32	4
Hangetham CF	52.54	3.39	44.07	0	0
Total	44.05	11.90	33.33	9.52	1.20

4.3.5 Dispersion of water

Dispersion of water bodies at a range of 0-25m from the fecal group encountered points was found in 61.90% cases and followed by 26-25m (20.24%) in the study area indicating availability of water in the study area could be an important habitat requisite for red panda distribution and occurrence (Table 5). There was significant difference between the no of red panda fecal group occurrence and presence of water bodies in the study area (χ^2=101.83, df=4, p<0.05).

Table 5: Dispersion of water source from red panda fecal groups

	Dispersion of water				
Study sites	0-25m	26-50m	51-75m	76-100m	>100m
	(% found)				
Choyatar CF	60	28	0	12	0
Hangetham CF	62.71	16.95	3.39	13.56	3.39
Total	61.90	20.24	2.38	13.10	2.38

4.3.6 Slope gradient

During the study period, direct (sightings) and indirect (fecal groups) evidences of red panda were found on steep slopes. Both of the sightings and 76.19% of the fecal groups found were at the slope of > 40^0. Use of slope gradient by red panda based on defecation sites are found more than 21^0 slope and not found below this (Table 6).

Table 6: Use of different slope gradient by red panda in the study area

	Slope gradient				
Study sites	0-5	6-20	21-30	31-40	>40
	(% used)				
Choyatar CF	0	0	28	16	56
Hangetham CF	0	0	3.39	11.86	84.74
Total	0	0	10.71	13.10	76.19

4.3.7 Slope aspect

In the study area, red panda used North-East and North-West slopes in high proportion for defecation. 46.43% and 32.14% of the red panda fecal groups were found on N-E and N-W facing slopes respectively (Table 7). Use of the slope aspect by red panda for defecation is found lower percentage in other aspects.

Table 7: Use of slope aspect by red panda in study area

	Slope aspect							
Study sites	N	N-E	E	S-E	S	S-W	W	N-W
	(% used)							
Choyatar CF	0	0	0	0	0	0	48	52
Hangetham CF	0	66.10	0	1.69	0	8.47	0	23.73
Total	0	46.43	0	1.19	0	5.95	14.28	32.14

Crown cover:

In the study area, highest (36.90%) of red panda fecal groups were found on the locations having canopy cover at the range of 26-50% , followed by 16-25% and 51-75% canopy cover respectively (Table 8). Very few (1.19%) fecal pellets were found in the closed (76-100%) canopy in the study area. The height of the over-storey canopy was considered not less than 5m. Canopy cover and presence of red panda fecal groups differed significantly (χ^2=62, df=5, p<0.05).

Table 8: Use of bamboo cover classes by red panda in the study area

	Crown cover						
Study sites	<1%	1-5%	6-15%	16-25%	26-50%	51-75%	76-100%
	(% used)						
Choyatar CF	0	8	0	40	44	4	4
Hangetham CF	0	0	8.47	28.81	33.91	28.81	0
Total	0	2.38	5.95	32.15	36.90	21.43	1.19

Bamboo cover:

In the study area, most of the red panda fecal groups (46.43%) were found on 26-50% bamboo cover range. At both of the study sites, 26-50% bamboo cover range was followed by 51-75% bamboo cover range (Table 9). Presence of red panda fecal groups differed significantly with different bamboo cover (χ^2=74.14, df=5, p<0.05).

Table 9: Use of bamboo cover by the red panda in the study area

	Bamboo cover						
Study sites	<1%	1-5%	6-15%	16-25%	26-50%	51-75%	76-100%
	(% used)						
Choyatar CF	0	0	0	0	40	36	24
Hangetham CF	0	0	10.17	13.56	49.15	23.73	3.39
Total	0	0	7.14	9.52	46.43	27.39	9.52

4.3.8 Relationship between Bamboo and environmental factors

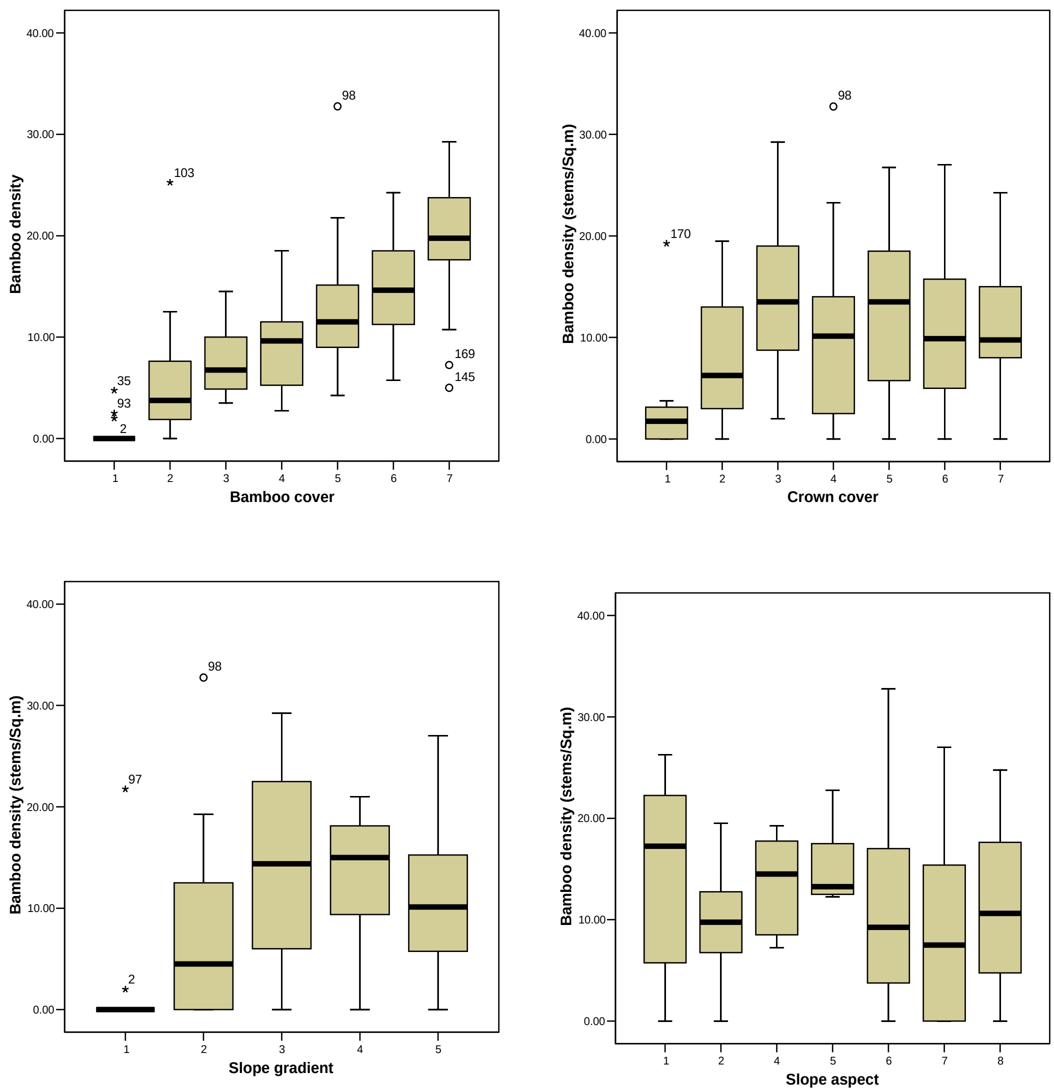


Figure 8: Relationship between bamboo density and four environmental factors. (a) Bamboo density to Bamboo cover (b) Bamboo density to crown cover (c) Bamboo

density to slope aspect and (d) Bamboo density to slope gradient. Code numbers of the environmental factor (Appendix 2).

There is a strong relationship between bamboo cover and bamboo density (Fig 8a). The Pearson correlations analysis indicates that the correlation is significant at the level of 0.05 ($P = 0.00$, correlation value is 0.731). This means that in this study there two variables can be interchanged to analyze the relationship between the bamboo and other environmental factors. Bamboo cover can fully represent the abundance of main food of the red panda in the study area. Bamboo density is negatively correlated with shrub density ($r= - 0.294$, $p<0.05$). Calculation showed that there is a significant association between bamboo density and altitude ($r=0.230$, $p<0.05$) i.e. as altitude increases, bamboo density also increases.

Kruskal-Wallis test indicated that there is significant difference between bamboo density across various crown cover ($p=0.016$) and slope gradient ($p= 0.00$) (Fig 8b, 8c, 8d) and no significance between bamboo density across the variant slope aspect ($p=0.189$).

CHAPTER 5: DISCUSSION

This study addressed distribution and habitat use of red panda in community managed forests of Ilam. With more than 62% of country's potential red panda habitat being outside the protected system of Nepal (Yonzon et al 1997) red panda conservation management requires information on how they are distributed and how they select habitat in these landscapes.

5.1 Distribution of red Panda

The study indicated the clumped pattern in fecal group distribution ($S^2/\bar{X} = 6.17 > 1$, $\chi^2=1148.33$, $p<0.05$) which was further supported by Kandel (2008) in Dhorpatan Hunting Reserve. Mahato (2004) also found distribution of red panda in patches of its habitat, broken by steep terrains and falls in Everest region. The clumped pattern of distribution is common in nature, almost the rule, when individuals are considered. Random distribution, relatively rare in nature, occurs where the environment is very uniform whereas uniform distribution occurs where competition between individuals is severe or where there is positive antagonism which promotes even spacing (Odum 1971).

Evidences of red panda (fecal groups) were found between the altitudinal ranges of 2200-2950m in the study area. The lowest altitude from where Pradhan et al (2001a) reported red panda was at 2400m ASL in Upper Phedi in Singhalila National Park. Yonzon (1989) reported red panda at elevation of 2990m asl in December which was the lowest altitude red panda being recorded in LNP and resembles with this study. I also recorded red panda at 2280m asl in December. The maximum number of red panda individual seen together or in a group was there on three occasions where in Singhalila National Park (Pradhan 1999b) whereas I recorded two red pandas together on single occasion in Choyatar CF. Mean altitudinal range of red panda distribution in Singhalila National Park was 3036±231m with a range of 2600-3600m. In Kanchenjunga conservation area, Mahato (2003) reported red panda fecal groups between 2800-3650m asl, where as Sharma (2008) reported the distribution of red panda between 3100-3600m inRara National Park. Similarly, Kandel (2008) recorded distribution of red panda in the altitude between 3000-3700m in Dhorpatan hunting reserve being abundant in the range between 3200-3500. In Langtang National Park, Yonzon and Hunter (1991b) reported red panda within an altitudinal range of 2800-3600m where as in Sagarmatha National Park red panda signs were found to be distributed within the altitudinal range between 2800-3400m (Mahato 2004). In Jamuna and Mabu VDCs of Ilam district, Williams (2004) reported red panda signs between 2400-3000m whereas Red Panda Network- Nepal (2008) reported red panda droppings between elevation of 2400-3300m in different community forests of Ilam and Panchthar districts.

These all studies the elevation where red panda are found gradually increases when one moves from east to west and Ilam harbors red panda in the lowest altitude of its distribution in Nepal. This is probably due to overall decrease in monsoonal rain towards the west because rainfall is one of the significant indicators of the red panda distribution (Yozon et al 1997). So, probably moisture along with other environmental variables could be responsible for lower distribution of red panda in eastern Nepal.

5.2 Relative sign abundance

In this study, expressed encounter rate as number of fecal groups encountered per km transect walk in different altitudinal range , it was found lowest in the altitudinal range of 2300-2500m with 2.09/km compared with 4.5/km in >2500-2700m and 12.14/km in >2700-2900m which is comparable with Pradhan et al (2001a) in Singhalila National Park, 20.31 ± 10.05 (at 2600 – 2800m) and 85.00 ± 42.00 (at 3100 – 3600m) with highest sign encounter rate (105.06 ± 53.59) at altitude range of 2800 – 3100m, sign encounter rate in term of number of sing encountered per 100 hours of search effort. RPN-Nepal (2008) recorded highest sign encounter rate 15.7/km in Dhanepa CF of Ilam district in 3200m while similar results was observed by Williams (2004) i.e. in 2400-2600m sign encounter rate 0.56/km, 2600-2800m (2.44/km) and 2800-3000m (5.1/km) in Jamuna and Mabu VDCs of Ilam and Mahato (2004) with encounter rate of 2/km at 2800m, 14.9/km at 3000m, 45/km at 3200m and 18.9/km at 3400m in Sagarmatha National Park. Kandel (2008) also encountered fecal pellets with the rate of 22, 20 and 6 per hour of search effort in different blocks of study area.

The density of the pellet groups showed lowest density in the altitudinal range of 2300-2500m with 12.5/ha compared with 31.8/ha in range of >2500-2700m and 42.857/ha in >2700-2900m asl which is apparently similar to the study of Pradhan et al (2001a) in Singhalila National Park where sign density was found to be 3.26/ha in oak forest (2600-2800m), 43.66/ha in the broadleaf deciduous forest (>2800-3100) and 39.19/ha in the subalpine forest (>3100-3600). The study area harbors comparable red pandas to Singhalila National Park in area proportion which was further supported by result of Williams (2004) with crude density 1 red panda/1.38 km^2 compared to 1 red panda/1.67 km^2 in Singhalila National Park. Possible reason of highest relative sign abundance in Choyatar in lower altitude (Table 1) may be due to disturbances towards the higher altitudes as there is a settlement at the top ridge at the elevation of 2865m. Below the settlement, near about 150m altitudinal range area is cleared up for firewood, timber collection and due to pressure of grazing with no tree coverage. Along with this, red panda prefers to feed on the new bamboo shoots and leafs which was more available in lower altitudes in Choyatar CF. Due to recent CF decision 2008 to proscribe grazing inside the community forest, bamboo sprouted well in lower altitudes.

5.3 Habitat Use

For wild animals inhabiting in mountainous regions characterized by dense forest, dense understory, and rugged cliffs direct observation and tracking to study habitat use is nearly impossible. One of the most effective approaches is to find feces lefts by animal in microhabitat and is used in several studies of red panda and other similar species by different researchers (Reid and Hu 1991, Wei et al 2000, Pradhan et al 2001a, Zhang et al 2002, 2004, Mahato 2004, Williams 2004). In its microhabitat, though red panda is found to defecate at the same site on different occasions (pile of fecal groups could be found in a single site and is mostly called as latrine site), there is no available evidence that its feeding sites are separated from its defecation sites. Previous studies carried out on the similar aspects revealed that the longer these species spent in a habitat, the more feces they left (Reid and Hu 1991, Wei et al 2000). I recorded all the fecal groups so as to assess the micro habitat use by the red panda in this study.

Index of similarity that compares vegetation in terms of which species present indicated species in systematic and red panda sign plot in the study area is almost similar (Sorenson's index of similarity, S = 70%). Floristic similarity is the response of species to the micro and macro environment (Krebs, 1994). Significant difference in diversity (Shannon-Wiener index) in systematic and sign plots ($t = 2.45$, $P<0.05$) could be due to the uneven i.e. clumped distribution of red panda signs in the study area where sign plots were deployed. Significance difference between slope, bamboo cover, bamboo height, bamboo diameter, proportion of dry shoots and shrub density between red panda sign plot and systematic plot (Table 2) indicate that these environmental factors may determine micro habitat use of red panda and hence its distribution pattern within its habitat. In similar study by Pradhan et al (2001a), bamboo cover, canopy cover and bamboo height differed significantly between animal plot and random plot in Singhalila National Park where as Williams (2004) found canopy cover, livestock disturbance and tree DBH were important to red panda presence.

Pradhan et al (2001a) found trees were most preferred site for defecation in Singhalila National Park and forest floor, rocks, fallen logs were also used where as Williams (2004), in Jamuna and Mabu VDCs of Ilam, reported the similar results. As this study was conducted in winter (December-January), we found use of rocks and forest floor (Table 4) in more proportion and is comparable with Pradhan et al (2001a) and Williams (2004). More proportion of fecal groups in rocks and forest floor in winter could be the communication strategies as winter happens to be a mating season for red panda (Pradhan et al 2001a). Three red pandas were observed on trees in Choyatar CF whereas Pradhan et al (2001a) made 81.25% of sightings on trees. Pradhan et al (2001a) recorded fecal groups on 13 species of trees more frequently in *A. densa, B. utilis, S. cuspidata, Q. pachyphylla, M. champbelli* and *Rhododendron spp.* in Singhalila National Park, Darjeeling, India. Williams (2004) also reported the use of 16 species of trees for defecation by red panda most frequently *Lithocarpus pachyphylla, Schefflera impressa*, *Magnolia champbelli* and noticed *Schefflera impressa* and *Sorbus cuspidata* as most preferred in proportion to their importance value. *Schefflera impressa*, *Rhodendron folconerii*, *Sorbus cuspidata* are found to be more important plant species for red panda as their important value is high in the sign plots (Appendix I and II) and percentage use for defecation.

Pradhan et al (2001a) noticed presence of water at a range of 0-100m from the animal centered plot in 79% cases in Singhalila National Park whereas Yonzon (1989) found the occurrence of droppings under different categories of distance to water were not evenly distributed and 90% of the dropping occurred between 0-100m. In this study area 97.62% of fecal groups found nearby water between 0-100m, averaged to 40.17±6.53 m with a range of 0-140m whereas Yonzon (1989) reported water dispersion averaged to 57.5±56m in LNP with a range of 0-400m. This result implies that apparently suitable habitat without a close source of water may not be preferred by red pandas. This may be due to the digestive physiology of red panda. The digestive strategy enables the red panda to maximize the rate of nutrient intake from ingested food to meet its daily nutrient requirements (Wei et al 1999a). Such a strategy is achieved by ingesting a large amount of food and discharging the digest fairly quickly through its gastrointestinal tract so as to extract maximum amount of nutrients.

For conservation of energy, red pandas rest most of the day (63%, Johnson et al 1988, 51-55%, Reid et al 1991) keeping its digestive tract filled with bamboo and other supplemental foods. In doing so, red pandas need to drink water frequently, and that's why may be it prefers areas having nearby source of water. In the study area, according to local herders, red panda first eats bamboo then drink water and then rests on the horizontal branches of trees. May be that's why local people usually say red panda get drunk after having water.

Given that the 10% area available (Figure 6), 19% of the of the fecal groups are encountered in slope class of > 40^0 (Table 6) which resembles with other related studies (Wang et al 1998, Wei et al 2000, Zhang et al 2004, Zhang et al 2006). Kandel (2008) encountered highest number of fecal groups on the slope of 34^0 in DHR while Karki (2009) found preferred slope for red panda is 37^0 in LNP. This revels that red panda prefers steep slopes. Use of steep sloped may be correlated with its feeding strategies as well as for safety and escape cover. On the steeper slopes, branches of trees and shrubs are more likely to intersect the leaf layer of bamboo. Red panda choose place with good access to new bamboo leaves (Zhang et al. 2004) and escape cover which happen to be associated with steeper slopes.

Red panda used North-East and North-West slopes in high proportion (Table 7) on their availability in the study area (Figure 5). Yonzon (1989) and Karki (2009) also found red panda to prefer Northern slopes in LNP and which was further supported by the result of Kandel (2008) in DHR.

Red panda highly uses medium (16-75%) canopy cover and differed significantly (χ^2=62, df=5, p<0.05) between the canopy cover classes. Very few (1.19%) fecal pellets were found in the closed (76-100%) canopy in the study area (Table 8) and Mann-Whitney *U* test showed there is no significant difference in canopy cover between sign and systematic plot. This finding somewhat contradicts with the study of Pradhan et al (2001a) and Williams (2004) which concluded red panda prefers closed canopy. This could be due to the difference in survey season. This study was carried out only in winter and we found red panda prefers to have sun bask which tend to happen in low canopy areas. Red panda did not use open canopy, may be to reduce the risk of predation.

Relatively more bamboo coverage area is preferred by red panda (mean value 50.36±4.53 %) and result showed presence of red panda fecal groups differed significantly with different bamboo cover classes (χ^2=74.14, df=5, p<0.05). More fecal groups (46.43%) were found on 26-50% bamboo cover range and followed 51-75% bamboo cover range. This indicates that red panda mostly use the area with bamboo coverage of 25 to 75%. Though bamboo density was found greater in red panda sign plot (12.72±0.96), did not differ significantly. The Mann-Whitney test showed significant different in bamboo height between systematic and red panda sign plots indicating red panda prefers taller bamboo clumps which is comparable with Pradhan et al (2001a) and Zhang et al. (2004). This may also be related with feeding strategy of red panda as it prefers to eat bamboo leaves (preferably emerging bamboo tips) from the horizontal branches of associated shrub/ tree species.

CHAPTER 6: CONCLUSION

The red panda distributed form 2200m to 2900m asl in study area of Ilam. Red pandas prefer the altitudinal range of >2700-2900m as this was the highest sign abundant range (42.857/ha and 12.14/km) in the study area. Direct sighting of 3 individuals, difference in fecal pellet size and local information indicate that breeding population of red panda is present. Red pandas use trees most rather than other substrate for defecation and water source dispersion is found one of the important environmental variables associated with the distribution of red panda (Mean dispersion 41.17±6.53)**.** Red pandas use more steep slopes and activities concentrates on northern slopes indicating one of the possible variable associated with its distribution. Red panda prefers high bamboo cover, taller bamboo and medium tree canopy cover in winter.

Community outreach programs could be beneficial for awareness rising in the local villages, but that is not sufficient for safeguarding red panda and its habitat in eastern Nepal. Along with conservation activities there is in need of reciprocal livelihood development programs directed to income generation to locals for sustainable conservation and protection of red panda.

Long term research on its specific requirements and conservation initiatives (Conservation awareness, school educational programs and sustainable development and wellbeing of local community) mutually can predict the future of red panda in the study area. Involvement of local community and developing community stewardship for red panda conservation can only support the future of the red pandas in areas outside the protected system.

CHAPTER 7: RECOMMENDATIONS

1. There is a very real need for further research on practical ways including contemporary research methods on ecology of red panda in eastern Nepal.
2. It is essential to maintain good canopy forest and to restore degraded habitat wherever possible. This will require improved law enforcement of illegal activities, forest management and the promotion of alternative human resources.
3. Landscape level concerted conservation efforts should be made so as to protect the red panda population in the region.
4. Future work should focus on developing and deliver conservation outreach programs and foster community effort in local stewardship for the in-situ conservation of red panda in the area.
5. It is necessary to understand the resource use interest of local people and their economic aspirations because mutual relationship with the local community will enhance the long term conservation initiative in these areas where the livelihood security of local people depends on the use of natural resources.

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Appendix I: IVI of tree species in red panda sign plot

Species	D	RD	D/ha	F	RF	BA	R BA	Dom	R Dom	IVI
Lali gurans	0.0171	26.9663	171.4286	0.3214	8.9109	0.0280	0.8443	4.8080	7.5487	43.4259
Bante	0.0061	9.5506	60.7143	0.3571	9.9010	0.2119	6.3792	12.8664	20.2006	39.6521
Ghonge Champ	0.0021	3.3708	21.4286	0.1429	3.9604	0.4009	12.0668	8.5898	13.4863	20.8175
Siltimur	0.0046	7.3034	46.4286	0.3214	8.9109	0.0397	1.1941	1.8417	2.8915	19.1058
Setikath	0.0021	3.3708	21.4286	0.1429	3.9604	0.2626	7.9044	5.6268	8.8343	16.1655
Kharane	0.0036	5.6180	35.7143	0.2500	6.9307	0.0479	1.4428	1.7117	2.6875	15.2361
Bhalu Chinde	0.0029	4.4944	28.5714	0.2143	5.9406	0.0984	2.9615	2.8109	4.4132	14.8482
Rani Champ	0.0007	1.1236	7.1429	0.0714	1.9802	0.7241	21.7975	5.1722	8.1206	11.2244
Lise	0.0021	3.3708	21.4286	0.1071	2.9703	0.1413	4.2534	3.0278	4.7538	11.0948
Silinge	0.0018	2.8090	17.8571	0.1786	4.9505	0.0906	2.7271	1.6177	2.5399	10.2994
Khannapa	0.0014	2.2472	14.2857	0.1071	2.9703	0.2203	6.6326	3.1476	4.9419	10.1594
Kurlingo	0.0025	3.9326	25.0000	0.1071	2.9703	0.0808	2.4331	2.0207	3.1725	10.0754
Panhele	0.0014	2.2472	14.2857	0.1429	3.9604	0.1485	4.4698	2.1212	3.3304	9.5380
Tenga	0.0011	1.6854	10.7143	0.1071	2.9703	0.1558	4.6890	1.6689	2.6203	7.2760
Katus	0.0018	2.8090	17.8571	0.1071	2.9703	0.0440	1.3231	0.7849	1.2323	7.0116
Kaulo	0.0014	2.2472	14.2857	0.0714	1.9802	0.1046	3.1489	1.4944	2.3462	6.5736
Phalant	0.0011	1.6854	10.7143	0.1071	2.9703	0.0851	2.5621	0.9119	1.4317	6.0874
Gogun	0.0018	2.8090	17.8571	0.0714	1.9802	0.0410	1.2342	0.7321	1.1494	5.9386
Chandan	0.0011	1.6854	10.7143	0.1071	2.9703	0.0433	1.3040	0.4641	0.7287	5.3844
Chimal	0.0011	1.6854	10.7143	0.1071	2.9703	0.0153	0.4600	0.1637	0.2571	4.9128
Kapase	0.0007	1.1236	7.1429	0.0714	1.9802	0.1049	3.1563	0.7490	1.1759	4.2797
Akhane	0.0007	1.1236	7.1429	0.0714	1.9802	0.0296	0.8917	0.2116	0.3322	3.4360
Asare	0.0007	1.1236	7.1429	0.0714	1.9802	0.0196	0.5913	0.1403	0.2203	3.3241
Kholme	0.0011	1.6854	10.7143	0.0357	0.9901	0.0338	1.0162	0.3617	0.5679	3.2434
Bhogate	0.0007	1.1236	7.1429	0.0357	0.9901	0.0315	0.9484	0.2251	0.3533	2.4670
Arupate	0.0004	0.5618	3.5714	0.0357	0.9901	0.0347	1.0430	0.1238	0.1943	1.7462
Bhojpatra	0.0004	0.5618	3.5714	0.0357	0.9901	0.0347	1.0430	0.1238	0.1943	1.7462
Kalo Jhingane	0.0004	0.5618	3.5714	0.0357	0.9901	0.0314	0.9461	0.1122	0.1762	1.7281
Futto	0.0004	0.5618	3.5714	0.0357	0.9901	0.0095	0.2862	0.0340	0.0533	1.6052
Phalame	0.0004	0.5618	3.5714	0.0357	0.9901	0.0082	0.2461	0.0292	0.0458	1.5977

Appendix II: IVI of tree species in Systematic plots

Species		D	RD	D/ha	F	RF	BA	R BA	Dom	R Dom	IVI
Bante	*Lithocarpus Pachyphylla*	0.0053	9.8020	52.9412	0.3529	11.3990	0.5715	8.9432	30.2544	41.6791	62.8800
Kharane	*symplocos theifolia*	0.0073	13.5644	73.2620	0.3102	10.0173	0.0551	0.8621	4.0361	5.5601	29.1418
Panhele	*Litsea salicofolia*	0.0043	8.0198	43.3155	0.2727	8.8083	0.0881	1.3793	3.8178	5.2594	22.0875
Lali gurans	*Rhododendron arboreum*	0.0073	13.4653	72.7273	0.1337	4.3178	0.0274	0.4280	1.9892	2.7404	20.5235
Kapase	*Acer chanpbelliip*	0.0023	4.2574	22.9947	0.1711	5.5268	0.2171	3.3981	4.9930	6.8784	16.6626
Kaulo	*Machilus edulis*	0.0021	3.9604	21.3904	0.1818	5.8722	0.1472	2.3037	3.1488	4.3379	14.1704
Phalant	*Quercus glauca*	0.0011	1.9802	10.6952	0.0963	3.1088	0.5425	8.4904	5.8025	7.9937	13.0827
Setikath	*Hymenodictyon excelsum*	0.0024	4.4554	24.0642	0.1230	3.9724	0.0785	1.2277	1.8879	2.6008	11.0286
Siltimur	*Zanthoxylum oxyphyllum*	0.0023	4.2574	22.9947	0.1390	4.4905	0.0337	0.5276	0.7752	1.0679	9.8158
Silinge	*Osmanthus suavis*	0.0022	4.1584	22.4599	0.0963	3.1088	0.0750	1.1739	1.6848	2.3210	9.5883
Chimal	*Rhododendron grande*	0.0018	3.3663	18.1818	0.0963	3.1088	0.0978	1.5306	1.7782	2.4497	8.9249
Ghonge Champ	*Magnolis campbelli*	0.0011	1.9802	10.6952	0.0856	2.7634	0.1913	2.9938	2.0461	2.8187	7.5623
Asare	*Viburnum erubescens*	0.0017	3.1683	17.1123	0.1070	3.4542	0.0192	0.3006	0.3287	0.4528	7.0754
Kholme	*Symplocos pyrifolia*	0.0013	2.4752	13.3690	0.1016	3.2815	0.0564	0.8830	0.7543	1.0391	6.7959
Bhalu Chinde	*Schefflera impressa*	0.0011	2.0792	11.2299	0.0695	2.2453	0.1453	2.2742	1.6320	2.2482	6.5727
Lise	*Ilex dipyrena*	0.0011	2.0792	11.2299	0.1016	3.2815	0.0679	1.0624	0.7624	1.0503	6.4110
Akhane	*Populus ciliate*	0.0012	2.2772	12.2995	0.0963	3.1088	0.0321	0.5021	0.3946	0.5437	5.9297
Angeri	*Lyonia ovalifolia*	0.0014	2.6733	14.4385	0.0535	1.7271	0.0315	0.4936	0.4554	0.6274	5.0278
Kalo Jhingane	*Eurya aristata*	0.0011	1.9802	10.6952	0.0695	2.2453	0.0348	0.5450	0.3724	0.5131	4.7385
Rani Champ	*Michelia doltsopa*	0.0001	0.1980	1.0695	0.0107	0.3454	1.7679	27.6660	1.8908	2.6047	3.1482
Tenga	*Sorbus cuspidata*	0.0004	0.6931	3.7433	0.0374	1.2090	0.1774	2.7766	0.6642	0.9150	2.8170
Khannapa	*Evodia fraxinifolia*	0.0005	0.8911	4.8128	0.0428	1.3817	0.0642	1.0046	0.3089	0.4256	2.6984
Jhingane	*Eurya acuminate*	0.0005	0.9901	5.3476	0.0428	1.3817	0.0324	0.5071	0.1733	0.2387	2.6105
Bajranth	*Quercus lamellosa*	0.0003	0.4950	2.6738	0.0267	0.8636	0.2380	3.7240	0.6363	0.8765	2.2351
Gogun	*Saurauia griffithii*	0.0005	0.9901	5.3476	0.0267	0.8636	0.0294	0.4594	0.1570	0.2163	2.0699
Katus	*Castonopsis hysterix*	0.0004	0.7921	4.2781	0.0267	0.8636	0.0333	0.5212	0.1425	0.1963	1.8519
Dabdabe	*Symplocos ramosissima*	0.0002	0.2970	1.6043	0.0160	0.5181	0.4287	6.7095	0.6878	0.9475	1.7627
Bhorlo		0.0003	0.5941	3.2086	0.0267	0.8636	0.0204	0.3191	0.0654	0.0901	1.5477
Sisi	*Lindera Pulcherrima*	0.0003	0.5941	3.2086	0.0267	0.8636	0.0186	0.2914	0.0597	0.0823	1.5399
Arupate		0.0002	0.3960	2.1390	0.0214	0.6908	0.1031	1.6132	0.2205	0.3038	1.3907
Khari	*Celtis australis*	0.0002	0.3960	2.1390	0.0214	0.6908	0.0233	0.3640	0.0498	0.0685	1.1554
Lampate	*Litsea kharsyana*	0.0002	0.3960	2.1390	0.0107	0.3454	0.0875	1.3698	0.1872	0.2579	0.9994
Kali Kath	*Aucuba himalaica*	0.0002	0.2970	1.6043	0.0160	0.5181	0.0216	0.3377	0.0346	0.0477	0.8629
Chandan	*Daphniphyllum himalayense*	0.0001	0.1980	1.0695	0.0107	0.3454	0.0573	0.8964	0.0613	0.0844	0.6278
Duware		0.0002	0.2970	1.6043	0.0053	0.1727	0.0096	0.1496	0.0153	0.0211	0.4909
Bhimsenpati	*Rhododendron spp*	0.0001	0.1980	1.0695	0.0053	0.1727	0.0175	0.2736	0.0187	0.0258	0.3965
Balu	*Pieris formosa*	0.0001	0.1980	1.0695	0.0053	0.1727	0.0128	0.1998	0.0137	0.0188	0.3895
Baunipate		0.0001	0.0990	0.5348	0.0053	0.1727	0.1511	2.3641	0.0808	0.1113	0.3830
Panchpate		0.0001	0.0990	0.5348	0.0053	0.1727	0.1453	2.2735	0.0777	0.1070	0.3787
Dudhilo	*Ficus nemoralis*	0.0001	0.0990	0.5348	0.0053	0.1727	0.0755	1.1816	0.0404	0.0556	0.3273
Sano Phalant	*Quercus oxyodon*	0.0001	0.0990	0.5348	0.0053	0.1727	0.0491	0.7685	0.0263	0.0362	0.3079
Timur	*Zanthoxylum armatum*	0.0001	0.0990	0.5348	0.0053	0.1727	0.0380	0.5951	0.0203	0.0280	0.2997
Futto	*Brassiopsis mitis*	0.0001	0.0990	0.5348	0.0053	0.1727	0.0347	0.5423	0.0185	0.0255	0.2972
Bhogate	*Maesa macrophylla*	0.0001	0.0990	0.5348	0.0053	0.1727	0.0177	0.2767	0.0095	0.0130	0.2847
Phirphire	*Acer oblongum*	0.0001	0.0990	0.5348	0.0053	0.1727	0.0113	0.1771	0.0061	0.0083	0.2801
Chaulane		0.0001	0.0990	0.5348	0.0053	0.1727	0.0079	0.1230	0.0042	0.0058	0.2775
Bhalayo	*Rhus spp.*	0.0001	0.0990	0.5348	0.0053	0.1727	0.0079	0.1230	0.0042	0.0058	0.2775

Appendix III : Floristic community parameters in different altitudes

Study Site	Parameters	Altitude						
		2300	**2400**	**2500**	**2600**	**2700**	**2800**	**2900**
Choyatar CF	Div. indx.	1.0221	0.8796	1.1378	1.1315	1.0302	*	*
	Dom. Indx	0.2188	0.2288	0.1029	0.0888	0.1114	*	*
	Evenness	0.7062	0.7007	0.8476	0.9196	0.8988	*	*
Hangetham CF	Div. indx.	*	*	1.0612	1.0617	0.9233	0.9001	2.2814
	Dom. Indx	*	*	0.1178	0.1167	0.1813	0.2002	0.1543
	Evenness	*	*	0.8454	0.8458	0.7668	0.7853	0.7893

Note: * No study carried out

Appendix IV: Codebook for thesis

Code Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Slope	0-5	6-20	21-30	31-40	>40			
Aspect	N	N-E	E	S-E	S	S-W	W	N-W
Bamboo cover	<1%	1-5%	6-15%	16-25%	26-50%	51-75%	76-100%	
Crown cover	<1%	1-5%	6-15%	16-25%	26-50%	51-75%	76-100%	