FEEDING ECOLOGY OF RED PANDA *Ailurus fulgens* F.G. CUVIER, 1825 IN PANCHTHAR, EASTERN NEPAL

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DECLARATION

I hereby declare that the work presented in this thesis has been done by myself, and has not been submitted elsewhere for the award of any degree. All literatures and data cited within this dissertation have been specifically acknowledged by reference to the authors.

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RECOMMENDATION

This is to recommend that the thesis entitled **"FEEDING ECOLOGY OF RED PANDA *Ailurus fulgens* F.G. Cuvier, 1825 PANCHTHAR, EASTERN NEPAL"** has been carried out by Miss Kamala Rai for the partial fulfillment of the requirement for Master's Degree of Science in Zoology with special paper of **"Ecology and Environment".** This is her original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institutions.

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CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Miss Kamala Rai entitled **"FEEDING ECOLOGY OF RED PANDA *Ailurus fulgens* F.G. Cuvier, 1825 PANCHTHAR, EASTERN NEPAL"** has been accepted as a partial fulfillment for the requirements of Master's Degree of Science in Zoology with special paper **"Ecology and Environment".**

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LIST OF ABBRIVIATIONS

CDB	Central Department of Botany
CDZ	Central Department of Zoology
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMOS	Complimentary metaloxide semiconductor
DCM	Digital Camera Module
DHM	Department of Hydrology and Meteorology
DNPWC	Department of National Parks and Wildlife conservation
GoVN	Government of Nepal
GPS	Global Positioning System
IAAS	Institute of Agriculture and Animal Science
IUCN	International Union for Conservation of Nature and Natural Resources
LNP	Langtang National Park
MoFALD	Ministry of Federal Affairs and Local Development
MoFSC	Ministry of Forest and Soil Conservation
NPWC	National Parks and Wildlife Conservation
PAs	Protected Areas
PHVA	Population and Habitat Viability Assessment
PIT	Panchthar, Iam Taplejung
SNP	Singhalila National Park

ABSTRACT

Despite being taxonomically a carnivore, the Red Panda *Ailurus fulgens* has diet that is overwhelmingly herbivorous. The diet choices of a species are based on their biology and availability of different types of resources. This study aimed to assess the seasonal diet composition, niche breadth and preference of food plants of Red Panda in Sidin area of Panchthar district, Nepal. In 2018, using altitudinal line intercept and quadrate methods reference plants' parts and fecal matter of the Red Panda were sampled. Micro-histological technique was used to prepare micro-photographs of reference food plants and fecal matters in laboratory. A total of 600 fragments of 30 fecal samples were analyzed to identify food remains in the fecal matter of Panda. Diet composition was expressed in terms of percentage of occurrence, Levin's niche breadth was used to understand feeding strategy and availability and use of different plant species were compared to determine the food preference of the Red Panda. Red Panda's diet composed of 10 different plant species belonging to seven families including seven trees, two shrubs and one herb with various proportions. Two shrubs of bamboo category; *Arundinaria maling* (49.33%) and *Arundinaria aristata* (39.83%) contributed 89.16 % of the overall diet. Other food plants were *Sorbus cuspidata* (2.17%), *Schefflera impressa* (0.33%), *Acer caudatum* (0.67%), *Vitex heterophylla* (0.5%), *Litsea salicifolia* (0.33%), *Litsea khasyana* (0.17%), *Rhododendron* spp (0.5%) and *Rubus* sp (0.84%). *Arundinaria* spp. was the major food item. *Sorbus cuspidata* was found to be the major supplementary diet contributing 2.17%. Other supplementary food plants were found to be consumed in nearly equal proportion (<1%). In addition, Arthopods' wings and appendages were found in very little proportions, which may be consumed along with the food plants. Niche breadth determination of Red Panda was found to be quite low; 0.0706, indicating its high selectiveness in forage. Among the seven consumed tree species, *Sorbus cuspidata* and *Acer caudatum* were found to be the most preferred species. Similarly, among the two consumed shrub species, *Arundinaria maling* was the highly consumed one whose availability frequency in the overall studied area was 59.15% and contribution in diet was 55.24%. Only one herb species (*Rubus* sp) was found to be consumed by the animal whose contribution in the overall diet was only 0.84%. Similar studies should be conducted about the species in other parts of the nation in order to explore the diet composition and diet preference on the basis of nutritional composition and their niche overlap as well as degree of competition with other species.

1. INTRODUCTION

1.1 General Background

Knowledge on the resource use, especially the diet is very important to understand the species ecology, evolution and inter-specific competition (Hobbs *et al*., 1983). Feeding ecology of mammals is in the center of interest of population biology and ecology (Green, 1987) as food plays an important role in species survival, growth and reproduction (Pekins *et al*., 1998). In addition, the information about feeding ecology of a species is important to understand their effects on vegetation and ecosystem as a whole (Barcia *et al*., 2007). Such knowledge plays a key role for the effective management as well as protection of wildlife species (Holechek *et al*., 1982; Mofareh *et al*., 1997), especially for endangered species (IUCN, 2015) like Red Panda, *Ailurus fulgens* F.G. Cuvier, 1825.

Feeding ecology of wildlife may be variable with season, habitat type, availability plant composition and population status (Korschgen, 1962). Body size as well as internal structure and physiology of the organism may also determine the quality and quantity of their diet. The diet that animal selects on pastures and rangelands generally differ from that which the animal would chooses in condition of complete freedom of choice (Dumont, 1997). Preferred diets are the one which are exerted by animal when no constraints bear on their choice (Hodgson, 1979), the situation which seldom occurs naturally at pasture. Selection is a function of preference, but it is obviously affected by the abundance and spatial distribution of preferred food plants. Selection is further influenced by some of the animals' foraging abilities; their ability to sort one food from the others, to digest the consumed food properly, to walk long distances and to learn and remember the location of food patches (Dumont, 1997). Preferences can be calculated in two ways: i) as the proportion of the total intake derived from each sward type; or ii) as the proportion of grazing time spent feeding on each patch (Dumont, 1997).

Identification of materials ingested by wild animals is a major problem in research of feeding habit of wildlife. Both direct observation and micro-histological techniques have been used for diverse species (Baumgartner and Martin, 1939). Rumen and fecal analysis are the indirect techniques. Fecal analysis through micro-histological technique has been the most widely used method for identification of undigested epidermal fragments in the faecal samples of herbivores (Baumgartner, 1939; Dusi, 1949). The method is often the only practical method available, particularly for some rare, endangered and evasive wild herbivores like Red Panda on which collection of ruminal samples are not easy because of their protection issues (Gonzalez and Duarate, 2007). Field work requires little equipment and can be used to compare different species or individuals of the same species simultaneously (Holechek *et al.,* 1982). In this technique, field work can be performed easily as sampling requires little equipments and does not require direct contact with the animal, although laboratory work is very tedious and time consuming.

1.2 Species Introduction

Red Panda (*Ailurus fulgens*) is a habitat specialist species preferring subtropical, temperate, sub alpine and alpine forest at elevations from 1500 to 4800 m (Yonzon and Hunter, 1991a; Pradhan *et al*., 2001a; Sharma and Belant, 2009). The Panda has been confirmed to the montane forests with dense bamboo-thicket understory of Bhutan, China, India, Myanmar and Nepal (Roberts and Gittleman, 1984). The Red Panda is commonly called as Pudhe Kudo by Rai community and Habre in Nepali.

Taxonomically this species belongs to the order Carnivora and family Ailuridae (Glatston *et al*., 2017). Family Ailuridae consists of two subspecies, *Ailurus fulgens fulgens* and *Ailurus fulgens styani* (Chakraborty, 1999 and Wei *et al*., 1999). The Red Panda is a monotypic species; the family, Ailuridae, has only one genus, *Ailurus* (Roberts and Gittleman, 1984). Red Panda is an indicator and unique species with specialized food habits; herbivorous diet being a member of Carnivora (Williams, 2004). Due to its specialized habitat and feeding behavior the species has been placed in the center of interest in conservation field (Glatston, 1994; Wei *et al.*, 1999a). It consists of simple and short gut, typical of carnivores and lacks cellulose digesting microbes (Roberts and Gittleman, 1984; Schaller *et al*., 1985). Panda has been physiologically adapted to lowering the metabolic rate to cope with low nutrients, reducing energy expenditure for maintenance and reproduction and this evolutionary strategy results in a long gestation period, low fecundity and slow postnatal growth which place constraints on rapid propagation of its population (McNab, 1989).

1.2.1 Morphology

The Red Panda averages 100 cm in length with its body being about 60 cm and tail about 40 cm long with alternating dark and light reddish rings (Williams, 2004). In general adult Red Panda weighs 4 to 5 kg (Yonzon, 1989; Roberts, 2001). Predominantly the Panda has a white face, with reddish brown "tear" marks extending from the inferior region of the orbit to the corner of the mouth, post-cranial dorsal pelage reddish-or orange-brown and ventral pelage glossy black, limbs are black more or less equal in size and soles of its feet are covered in a dense mat of wool (Roberts and Gittleman, 1984). It consists of enlarged ‘false-thumb’ which contributes in gripping actions especially it is used to grasp food items (Anton *et al.*, 2006). There is no sexual dimorphism in body size as well as in coat color (Roberts, 1981).

1.2.2 Ecology

1.2.2.1 Life Cycle and Behavior

The average life span of Red Panda is about 8-10 years in wild (Johnson *et al*., 1988; Yonzon and Hunter, 1991b; Pradhan *et al.*, 2001b). It is solitary, except for a brief mating period and the time when a mother and its young are together (Yonzon, 1989). Mating

season has been observed between January and March, with mean gestation period of 134.2 days (Roberts and Gittleman, 1984; Pradhan *et al.*, 2001b). Female makes nests in tree hollows, bamboo thickets or rock crevices and gave birth of 1 to 4 young (Dittoe, 1944; Roberts and Kessler, 1979) and they reach adult size at approximately 12 months of age (Bircher, 1989). Probability of activities is highest in autumn and winter, due to the patchy distribution of fruits in autumn and mating season in winter (Yonzon, 1989). Probably to avoid human and other animal's disturbances it is mostly active at dusk and dawn and rest during daytime. Average home range is usually found to be 5.12 sq.km for male and 2.37 sq.km for female (Thapa and Basnet, 2015).

1.2.2.2 Habitat Use

The Red Panda habitat is typically characterized by the presence of mixed deciduous and coniferous forests with a bamboo-thicket understory (Roberts and Gittleman, 1984; Chakraborty, 1999). Pradhan *et al*., (2001a) reported that 79% of habitats are within 100 m from the water bodies, indicating that the presence of water is an important habitat requisite for this species. The Panda prefers less disturbed habitats (Acharya, *et al*., 2018) and the preference of habitat also seems to be dependent on the availability of palatable food items according to season (Chalise, 2013). Fallen logs, tree stumps and shrubs are important habitat elements for Red Panda, providing substrates suitable for defecation (Pradhan *et al*., 2001a) and structural access to bamboo leaves (Wei *et al*., 1999b). Similarly, the habitat with southwest facing gentle to steep slopes (36˚ - 45˚) and the north, north-west and south-west aspects have been found to be highly preferred by the Red Panda (Yonzon and Hunter, 1991a; Kandel, 2009; Dorji *et al*., 2012; Bhatta *et al*., 2014).

1.2.2.3 Food Habits

Red Panda is a unique member of order Carnivora with herbivorous in feeding depending chiefly on young leaves and shoots of bamboo (Yonzon and Hunter, 1989). Major genera of bamboo being eaten by the Panda are *Arundinaria, Thamnocalamus, Phyllostachys, Oionobambusa, Semiarundinaria* and *Pseudostachyum* and also eats wild fruits, berries, mushrooms, acorns, lichen, succulent grasses also rarely feed on bird eggs, insects and grubs in wild, while in captive condition the animal has shown particular interest in sweet food and meat (Warnell *et al.,* 1989; Yonzon & Hunter, 1991a; Pradhan, *et al.,* 2001b; Choudhury, 2001; Panthi *et al.,* 2012; Sharma *et al.,* 2014; Thapa and Basnet, 2015).

The dietary items are varied according to season and their availability but the major food item, contributing almost about 90% is the bamboo (Pradhan, *et al.*, 2001b; Panthi *et al.*, 2012; Sharma *et al.,* 2014; Thapa and Basnet, 2015). The digestive system of the Red Panda is ill-adapted for proper digestion and utilization of its low nutrients of bamboo diet (Roberts and Gittleman, 1984; Bleijenbery and Nijboer, 1989) so it consumes bamboo leaves in large amount to fulfill its energy requirements (oftedal *et al*., 1989). Although, Red Panda is scansorial, it forages primarily on the ground (Roberts and

Gittleman, 1984). Distinct latrine areas are used for regular defecation but not urination (Roberts, 1981).

1.2.2.4 Geographical Distribution

Geographical distribution of the Red Panda can be considered as disjunct (Roberts and Gittleman, 1984). Red Panda is known to be occurred throughout the narrower Himalayan range of Nepal, India, Bhutan, Myanmar, and southern China, with a distinct population on the Meghalaya Plateau of north-eastern India (Choudhury, 2001). Two subspecies are biogeographically separated by the Salween (Nu Jiang) River in China (Choudhury, 2001; Wang *et al*., 2008). *A. f. fulgens* occurs in the west in Bhutan, Nepal, India, northern Myanmar and China (southern Tibet and western Yunnan) while *A. f. styani* occurs in the east, in south-central China (Sichuan and Yunnan). Red Panda's western most occurrence is recorded so far in Api Nampa conservation area, the westernmost part of Nepal (DNPWC, 2011) and eastern most in the Minshan mountains and upper Min Valley of Sichuwan Province, south-central China (Wei *et al*., 1999a; Chaudhary, 1997). In the north its geographical range is surrounded by the Namlung Valley and in the south it extends to Liakiang range in western Yunnan (Roberts and Gittleman, 1984).

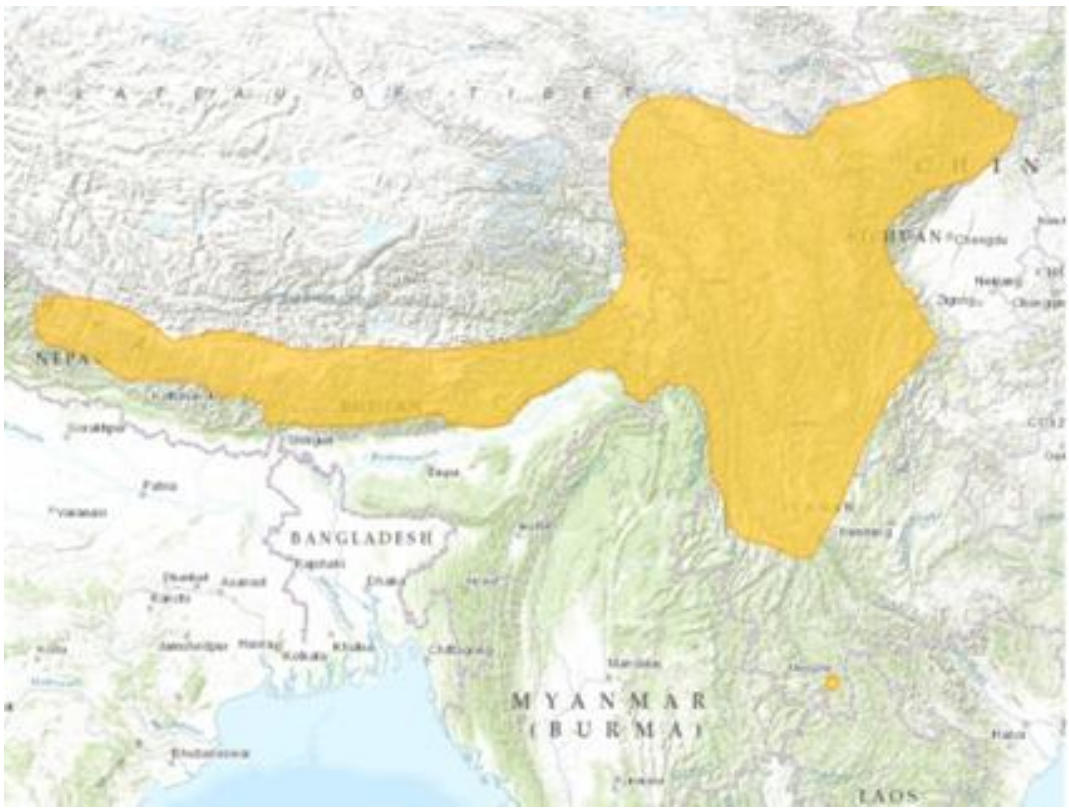

Figure 1: Global Distribution of Red Panda (Source: IUCN, 2015)

On the basis of the habitat suitability index, Nepal is home to approximately 1.9% of the estimated global population of the Red Panda (Bista and Poudel, 2013). Presence of Red Panda had been confirmed in nine Protected Areas (PAs) of Nepal: Kanchanjungha

Conservation area (Yonzon, 1996; Mahato, 2003; Mahato and Karki, 2005; RPN, 2010), Sagarmatha National Park (Mahato, 2004), Makalu Barun National Park (Jackson, 1990), Langtang National Park (Yonzon *et al*., 1991; Karki, 2009; Thapa and Basnet, 2015), Rara National Park (Sharma, 2008; Sharma *et al*., 2014), Manaslu Conservation Area (Yonzon, 1997), Dhorpatan hunting reserve (Sharma and Kandel, 2007; Sharma and Belant, 2009; Subedi, 2009) and Annapurna Conservation Area (Shrestha and Ale, 2001). Its presence had also been recorded from Api Nampa Conservation Area, the westernmost part of Nepal (Jnawali, *et al*., 2011). The species had also confirmed in 24 districts; Taplejung, Panchther, Ilam, Therathum, Sankhuwasabha, Ramechap, Dolakha, Nuwakot, Sindhupalchowk, Pyuthan, Rasuwa, Gorkha, Manang, Baglung, Myagdi, Rukum, Rolpa, Mugu, Darchula, Doti, Acham, Bajura, Bajhang, (Jnawali *et al*., 2012) with potential habitats in other 12 districts; Bhojpur, Khotang, Okhaldhunga, Dhading, Lamjung, Kaski, Mustang, Dolpa, Jajarkot, Humla, Jumla, Kalikot (Jnawali *et al*., 2012).

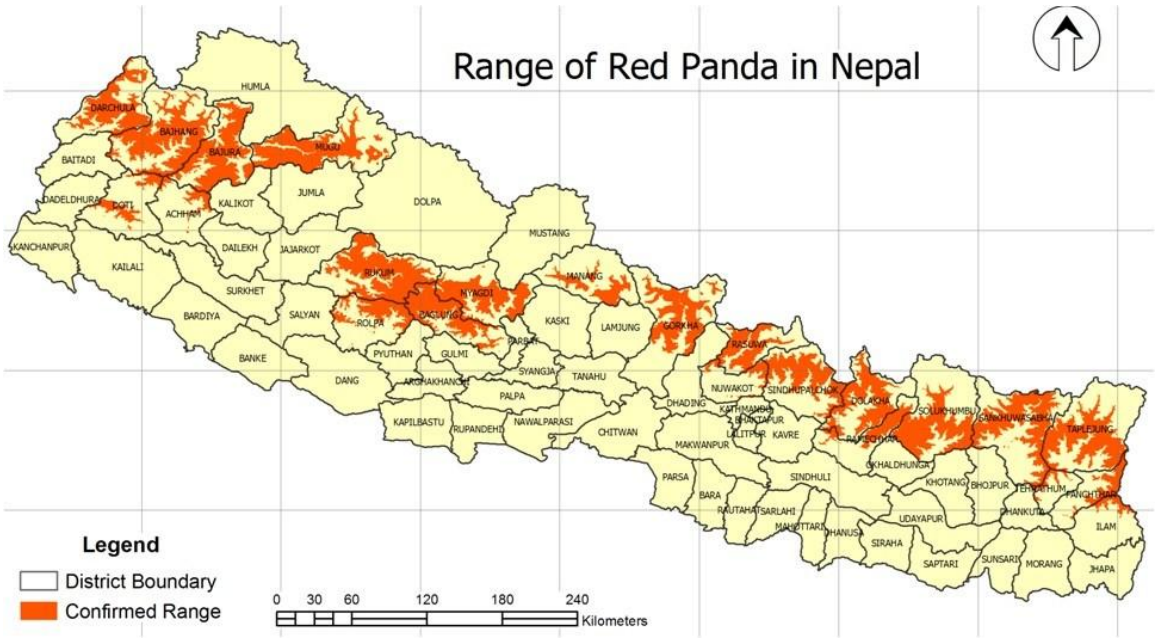

Figure 2: Potential habitat of Red Panda in Nepal (Source: RPN, Nepal, 2016)

1.2.2.5 Population, Threats and Conservation Status

The exact size of the world's wild Red Panda population is not available due to the fact that remote and rough terrain it occupies. The estimated global population of the Red Panda is about 16,000-20,000 within the potential habitat of 142,000 sq. km in five countries (Choudhury, 2001). In Nepal, Yonzon (1989) estimated a total of 73 individuals in LNP. Recently, 317-582 individuals have been estimated across Nepal (DNPWC, 2011). Jnawali *et al.*, (2012) suspected 237 to 1,061 individuals of Panda in Nepal. In the recent days, major threats facing by the Red Panda include habitat loss, poaching, inbreeding depression, parasitic infection, etc. (Choudhury, 2001; Bista and Poudel,

2013). Knowing the ecological significance of the species and to minimize the threats, Red Panda is protected throughout its distribution range and is listed in Appendix I of the International Trade of Endangered Species (CITES) since 1996 (Wei *et al.*,1999; Choudhury, 2001; Pradhan *et al*., 2001a). The global conservation status of Red Panda is endangered with its declining population (IUCN, 2015). It is legally protected by the Government of Nepal under section 10 of the NPWC Act 1973 (DNPWC, 2011).

1.3 Objectives

The general objective of the study was to gather information on feeding ecology of Red Panda in Panchthar, Eastern Nepal. The specific objectives were to;

- Determine diet composition,
- Determine the dietary niche breadth and
- Assess the availability and use of food resources by the Red Panda in Panchthar, Eastern Nepal.

1.4 Rationale of the Study

Globally, Red Panda's population is declining day by day because of habitat destruction, mass-bamboo flowering, poaching, parasitic infection and human-driven climate change (Zhang *et al.*, 2008; Kandel, *et al.*, 2015; Bista *et al*., 2017). The Red Panda needs protective measures as it is a monotypic (Roberts and Gittleman, 1984) and indicator species with specialized food habits (Williams, 2004). The most pressing problem in the conservation of the Red Panda is insufficient information regarding its status, habitat, distribution and feeding behavior, especially outside the protected areas (Panthi, *et al*., 2012). In Nepal, very limited studies have been conducted about the feeding behavior of the animal (Yonzon, 1989; Karki, 2009; Panthi *et al*., 2012; Sharma *et al*., 2014; Thapa and Basnet, 2015) and all of them are within the protected areas. In our country about 62 percent of potential habitat of the species lies in community managed and national forest and only about 38 percent lies in PAs (DNPWC/MoFSC/GoN, 2018). Realizing these facts, the study was focused on food habits of Red Panda outside of the protected area for the first time. The current study will generate knowledge about diet composition of the species and may to increase biological knowledge of the species. The information could support for the further investigation about the species and in making protection as well as management decisions.

1.5 Limitations of the study

Study in the mountainous terrain itself was challenging and adventurous due to its highly uneven topographic structure and harsh climatic condition. The limitation faced during the study was;

- Field-time was during monsoon season so heavy rainfall made very difficult in collection and storage of samples.

2. LITERATURE REVIEW

2.1 Behavior and Habitat Use

Red Panda, *Ailurus fulgens* is a rare and elusive mammalian species endemic to the Eastern Himalayas with its known distribution only in five countries worldwide; Nepal, India, China, Bhutan and Myanmar at elevation between 2,200m to 4,800m (Roberts and Gittleman, 1984; Glatston, 1994; Yonzon *et al*., 1997; Wei *et al*., 1999; Choudhury, 2001; Pradhan *et al*., 2001a; Dorji *et al*., 2012; Ghose and Dutta, 2011). Roberts and Gittleman (1984) reviewed distribution, fossil structures, ontogeny and reproduction, ecology, behavior and genetics of the species and reported the species is usually solitary except breeding season. The ecology and behavior of the Red Panda has been studied by various researchers and reported different facts. Johnson *et al*. (1988) reported the Red Panda subsists almost exclusively on bamboo leaves and occupies home-range of 3.4 sq. km in the Wolong Reserve, China. Yonzon (1989) reported the species occur between 2900m-3900m altitude, used fir-jhapra (bamboo) as preferred habitat and estimated variable home range (1.4-11.6 sq. km) in Langtang National Park, Nepal.

The exact population of Red Panda in different areas of the world has not been known but some estimates are available. Yonzon & Hunter (1991a) reported occurrence of about 40 adult Pandas in four or more fragmented sub populations in LNP. They reported high rate of cubs mortality and the major causes (57%) of their death were human-related and Yonzon and Hunter (1991b) suggested the restriction in the number of chauri (yak-cattle hybrids) in the area to increase survival rate. Choudhury (1997) reported the presence of Red Panda throughout the north-eastern India; Sikkim, Darjeeling, Arunachal Pradesh along with Garo Hills area of Meghalaya, which is a tropical forest with 1412 m of the highest peak. Wei *et al*., (1999a) investigated both species of Pandas in China and estimated numbers were about total of 6000–7000, including 3000–3400 in Sichuan, 1600–2000 in Yunnan and 1400–1600 in Tibet province.

Red Panda is a habitat specialist and prefers subtropical, temperate, sub alpine and alpine forests mainly characterized by the presence of ringal bamboo dominated understory (Pradhan *et al*., 2001a; Mahato and Karki, 2005; Chalise, 2009; Sharma and Belant, 2009; Bista *et al*., 2017). Pradhan *et al.,* (2001a) reported the bamboo cover, height, canopy cover and water availability as important habitat components for Red Panda in the Singhalila National Park, Darjeeling, India. Williams (2004) reported Red Panda in Jamuna and Mabu Village Development Committees (VDCs) of Ilam, Eastern Nepal with density of 1 Red Panda/1.38 sq. km, and preferred habitat were undisturbed mixed broadleaf forest between 2800m – 3000m of elevations. Predation was the greatest threat to the population. Sharma and Belant (2009) reported Red Pandas in Dhorpatan Hunting Reserve, Nepal, with markedly increased frequency of pellets from 3,000m to 3,500m and then declined sharply at higher elevations. No any signs were observed at elevations greater than 3,600m. Panthi *et al*., (2012) studied the summer diet and distribution of the Red Panda (*Ailurus fulgens fulgens*) in Dhorpatan Hunting Reserve, Nepal and reported the evidences of Red Panda predominantly in forests comprising plant communities

dominated by *Abies spectabilis, Acer caesium, Tsuga domusa,* and *Betula utilis,* with ground cover of *Arundinaria* sp. Bhatta *et al*., (2014) studied the distribution of Red Panda in Jumla district, Nepal with preferred habitat at the elevation range of 2900m - 3000 m with southwest facing steep slopes (36˚ - 45˚), associated with water sources at the distance of ≤100 m. Chakraborty *et al*., (2015) reported the healthy abundance of Pandas throughout the higher areas of the Pangchen Valley, Arunachal Pradesh, India and their preferred areas were above 2800 m of elevation with dense bamboo cover of *Arundinaria* sp. and dominant trees such as *Rhododendron* sp, *Sorbus* sp, *Abies* sp, etc. Thapa *et al.,* (2018) reported that the genetic diversity of Red Pandas is high in China, but information about the subject is lacking from other ranges which makes subspecies classification unclear.

2.2 Diet of Red Panda

Roberts and Gittleman (1984) reported bamboo as a dietary staple of Red Panda. Various genera of bamboo eaten by the animal included *Phyllostachys, Sinarundi-naria, Thamnocalamus, Chimonobambusa, Qiongzhuea,* etc. In addition to bamboo, Red Panda may eat small mammals, birds, eggs, blossoms, and berries. Yonzon (1989) reported 54-100% of droppings comprised *Thamnocalamus* sp. i.e. jhapra leaves in LNP, Nepal indicating jhapra as major food item followed by *Sorbus* fruits and mushroom. Yonzon and Hunter (1991a) reported that there is no direct food competition between livestock and Pandas in LNP, Nepal, as chauri consumed bamboo leaves at a lower height than Pandas, but may cause depressed bamboo abundance by trampling which may lead to the food scarcity to the Pandas. Reid and Huang (1991) found *A. f. styani*'s diet consist of 93.7% bamboo leaves supplemented with bamboo shoots and fruits of various shrubs in the Wolong Reserve (WR), China.

Wei *et al*., (1999b) suggested that microbial digestion only played a minor role in Panda's digestive strategy as a result it consumes large quantities i.e. over 1.5 kg of fresh leaves and 4 kg of fresh shoots of bamboo daily in order to survive on the poor-quality diet. Pradhan *et al*., (2001b) found 83 – 92% of *A. f. fulgens'* diet consisted of bamboo leaves complemented with bamboo shoots, and fruits of various trees and shrubs in SNP, India. Zhang *et al*., (2009) reported that the Panda seemed to select most nutritious food items to feed on. The animal almost exclusively fed on *Bashania faberi* along with new shoots and fruits of *Sorbus*, and *Rubus* as these are nutritious and digestible. Karki (2009) reported *Thamnocalamus aristatus* as the highly preferred food of Red Panda. Panthi *et al*., (2012) reported that dominant plant found in scat of the Red Panda was *Arundinaria* sp. (81.7%), with *Acer* sp., *Betula utilis,* and lichen in Dhorpatan Hunting Reserve, Nepal. Sharma *et al*., (2014) reported bamboo as the dominant food item (80–100%) of Red Pandas in both the pre-and post-monsoon seasons. Thapa and Basnet (2015) studied the seasonal diet of Red Panda in LNP, Nepal and found that the Red Panda's diet composed of eight different plant species including *Thamnocalamus aristatus, Sorbus cuspidata,* moss, *Juniper recurva, Acer caudatum, Rhododendron campanulatum, Abies spectabilis, and Rubus* sp. Its diet consisted of *Thamnocalamus aristatus* (mean=245.08±15.74%) in highest proportion statistically, in all seasons. Panthi *et al.,* (2015) reported that the

geometric analysis of macronutrient balance of seasonal diets of the animal were similar in nutrient balance to the most frequently consumed *Arundinaria* sp. indicating *Arundinaria* sp. as the major diet. They reported the seasonal nutrient preferences of the Panda; increased carbohydrate intake in winter for thermogenesis, and increased protein and lipid intake in early summer to support reproduction and lactation; however, these differences may also indicate differences in resource availability.

It can be concluded that the major food item of Red Panda is bamboo of any species throughout the year which are available within its habitat range and it is supplemented by other surrounding species and also sometimes by small mammals, birds, eggs, blossoms and berries.

2.3 Dietary Niche Breadth

Niche breadth is a parameter that is often used to measure how general or specialized a species is within a given environment. Wider the niche breadth of a particular animal, it is more generalist and narrower the niche breadth, it is more specialist (Smith, 1980). A specialist uses few food sources of its surrounding than a generalist (Shipley, *et al*., 2009). Sharma *et al*., (2014) reported low niche breadth (0.02 in pre-monsoon season and 0.06 in post-monsoon seasons) of the animal. Similarly, Thapa and Basnet (2015) reported very low; 0.000104 niche breadth of Red Panda in LNP, Nepal. These reviews show that the animal is highly specialized feeder.

2.4 Micro-histological Analysis

Knowledge of dietary composition of species has become an increasingly important for the conservation and management plan. Among various methods, micro-histological technique, first introduced by Baumgartner and Martin (1939) has become the preferred one for determination of diet composition of herbivores. The micro-histological technique involves collection of diet samples, which can be from esophageal or rumen of fistulated animals, intestinal digesta of dead animals, or fecal samples. The undigested vegetative fragments in the samples are identified by comparison with reference slides, micro-photographs or hand-drawn figures of reference diet species (Johnson *et al*., 1983). The micro-histological technique is based on three assumptions (Havstad and Donart, 1978; Sparks and Malechek, 1968; Fracker and Brischle, 1944): (i) the fragments of plants are randomly distributed on microscope slides, (ii) percentage frequency can accurately estimate particle density and this measurement directly predicts dry weight percent composition of the sample, and (iii) ratios of identifiable to non-identifiable particles within a species are equal to one i.e. every species is as identifiable as another.

The accuracy of the micro-histological technique for faecal analysis can be affected by the extent of digestion of different plant species (Slater and Jones, 1971; McInnis *et al*., 1983). The technique may also be biased because of poor trainings (Holechek and Gross, 1982), method of sample preparation (Vavra and Holechek, 1980) and magnification of microscope (Holechek and Valdez, 1985). Results from faecal analyses can be improved by species-specific correction factors that compensate for differential digestibility of

ingested forages (Voth and Black, 1973; Dearden *et al*., 1975; Fitzgerald and Waddington, 1979). Micro-histological analysis is being used to determine the diet composition of many families of mammals since many years. Such as; Cervids like deer, elk and moose (O'Bryan, 1983; Kirchoff and Lorensen, 1998), Leproids like rabbits and hares (Adams *et al*., 1962; Sparks, 1968) and Equids like wild horses (Hansen *et al*., 1977). In Nepal, this method has been applied in diet analysis of Rhino (Jnawali, 1995; Pradhan *et al*., 2008), Swamp Deer (Pokharel, 1996), Asian Elephant (Steinheim *et al*., 2005, Pradhan *et al*., 2008), Gaur (Chhetri, 2006), Barking Deer (Nagarkoti and Thapa, 2007), Wild Sheep (Shrestha and Wegge, 2008), mountain domestic and wild ungulates (Shrestha *et al*., 2005), Red Panda; (Panthi *et al*., 2012; Sharma *et al*., 2014; Thapa and Basnet, 2015), Himalayan musk deer (Magar, 2016) and Four-Horned Antelope (Kunwar *et al*., 2016).

3. MATERIALS AND METHODS

3.1 Study Area

3.1.1 Location and boundaries

The study was conducted in Sidin area of Falelung Rural-Municipality, Panchthar district (26˚53' - 27˚29' N, 87˚32' - 88˚02' E), Eastern Nepal (Figure 3). The district is bordered with Ilam in the South East, Dhankuta in the South West, Terhathum in the North West, Taplejung in the North and West Bengal and Sikkim of India in the East. It is a hilly district and covers 1,241 sq. km. of area with altitudinal variation from 300m - 5000m (CBS/ GoVN, 2011). The Panchthar-Ilam-Taplejung (PIT) corridor has been considered as an important habitat for the Red Panda as it contains 178 sq. km or 20% of total potential Red Panda habitat of Nepal, which support approximately 25% of Nepal's red Panda population, with an estimated 100 individuals (Williams, 2004; Williams, 2006; Williams *et al.*, 2011). The northern portion of the PIT corridor consists of approximately 66.8 sq. km of Red Panda habitat area with an estimated Panda population of 28 individuals, based on a crude relative density of one individual per 2.42 sq. km. The current study was focused in Sidin (2200m-3400m) area of Phalelung Rural-municipality which is located in the eastern part of the district, covering an area of 207.14 sq. km. The area consists of 5,565 hector forests and 20,320 hector is used as farmland (MoFALD/GoVN, 2018).The Rural-Municipality holds by a total population of 21884 in 4841 households (MoFALD/GoVN, 2018). The area makes direct connection with West Bengal and Sikkim of India towards its North-East boundary.

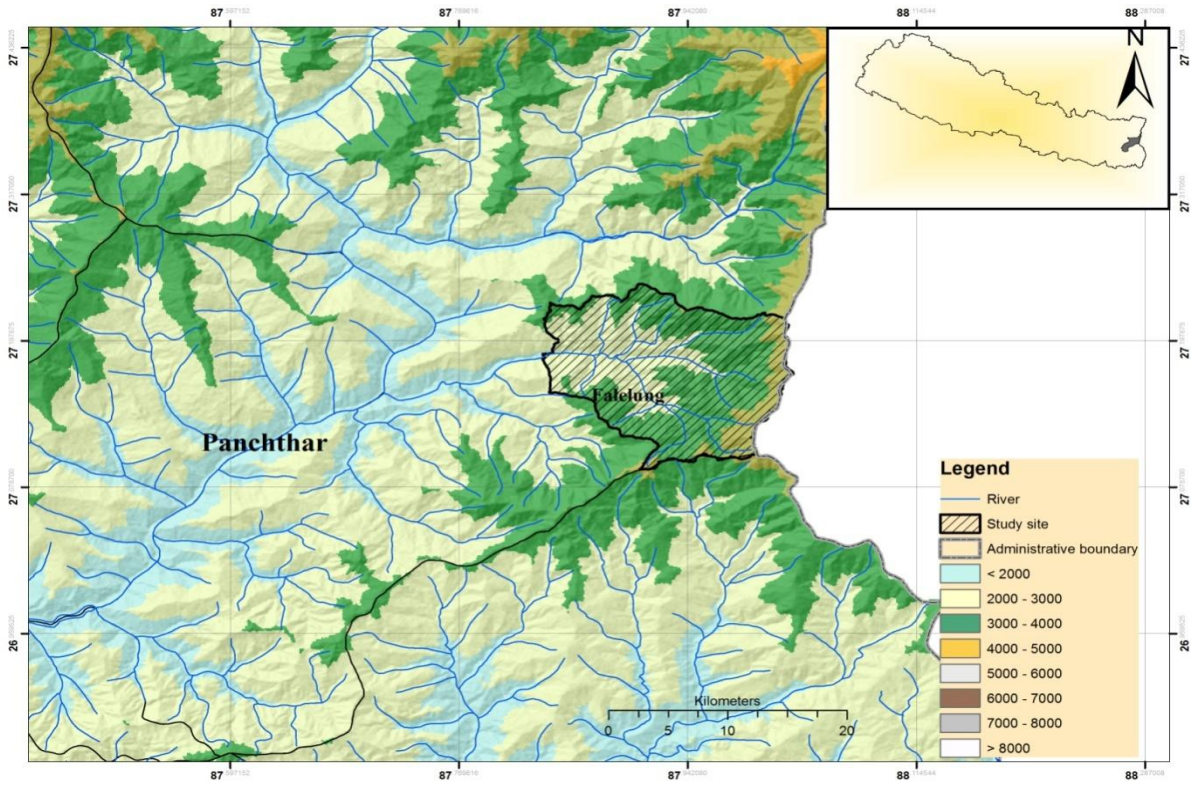

Figure 3: Map showing study areas in Panchthar district, Nepal.

3.1.2 Climate

The climatic data of Phidim (27˚9ˈN, 87˚45ˈE and elevation 1,205m), Panchthar district has been used for the analysis. The area is characterized by monsoon climate pattern. Early May brings dense cloudy days with daily afternoon showers beginning by early June. In the beginning of October the monsoon ends off and cooler, clear days begin in the middle of the month. During the months of December to February snowfall occurs at time to time. By mid April to early May, the forests become beautifully coloured with whites, yellows, pinks, and blood reds of *Rhododendrons, Magnolia*, *Symplocos*, etc. flowers. The average maximum rainfall between 2013 and 2017 was 262.44 mm during August with about 91 % of the average 5 years rainfall occurring from May to September (Figure 4).

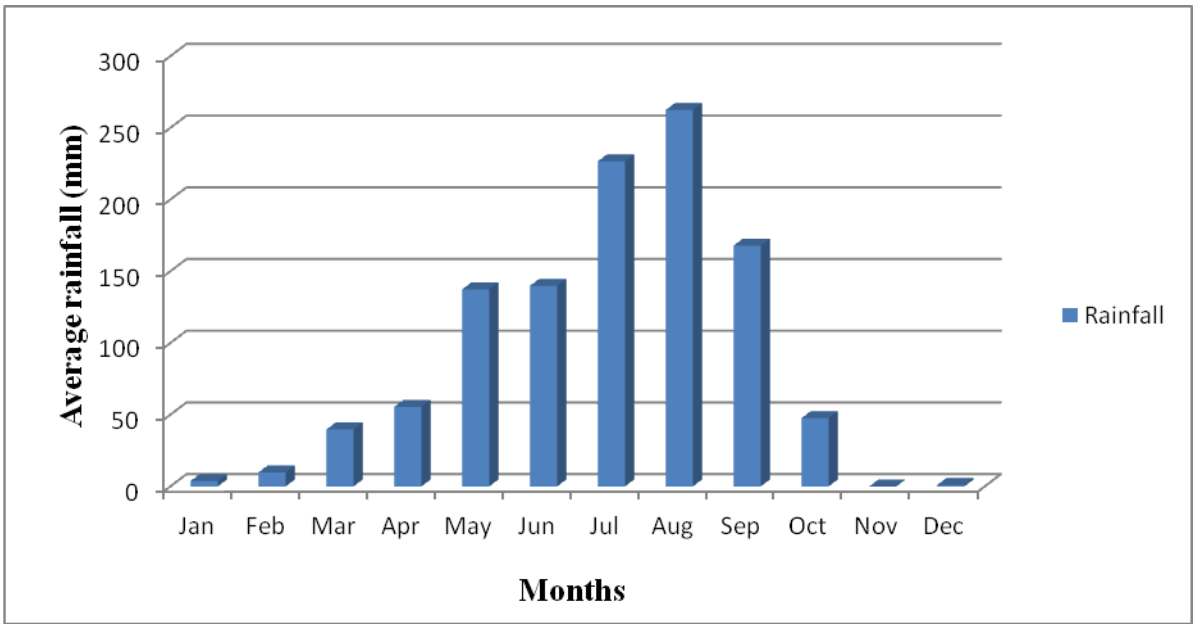

Figure 4: Average monthly rainfall (2013-2017) at Phidim, Panchthar, Nepal. (Data source: DHM/GoVN)

The average monthly maximum temperature of the period between 2013 and 2017 was recorded to be 30.86˚C; likewise the average monthly minimum temperature was 7.56˚C (Figure 5). The temperature can reach as high as 33˚C from April to August and then slowly starts to decrease from September. Winter temperature falls almost to freezing point.

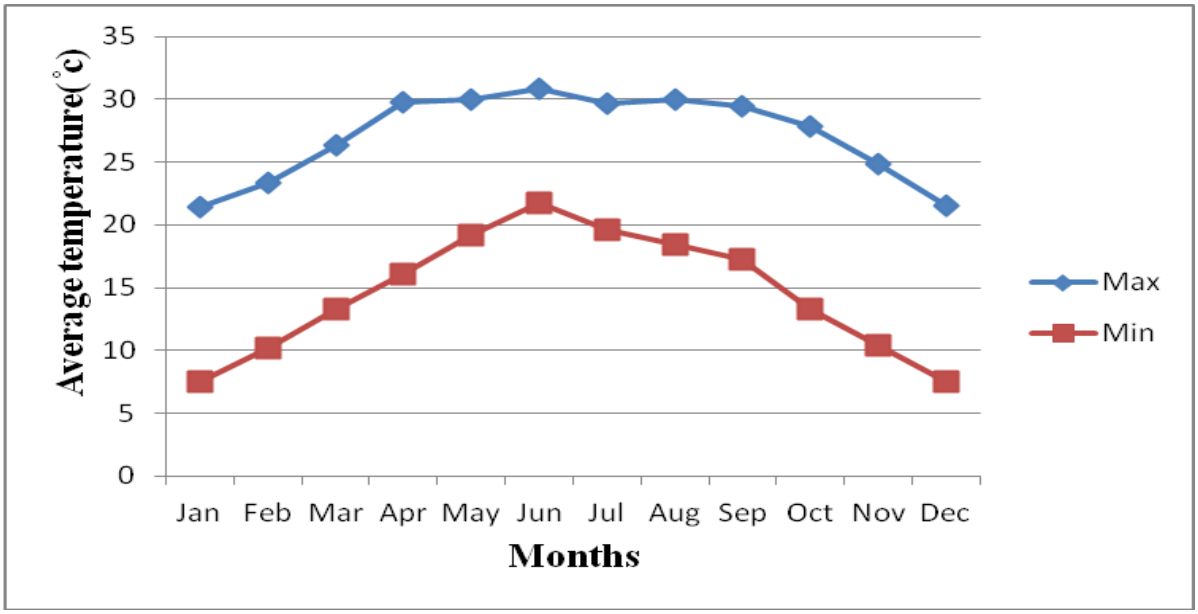

Figure 5: Average monthly maximum and minimum temperature (2013-2017) at Phidim, Panchthar, Nepal. (Data source: DHM/GoVN)

The average relative humidity drops down to below 60% and the average temperature warms up reaching up to 30.86˚C. The average monthly relative humidity of the period between 2013 and 2017 was recorded maximum 87.16% in the month of August at morning time and minimum was 55.98% in the month of April at evening time (Figure 6).

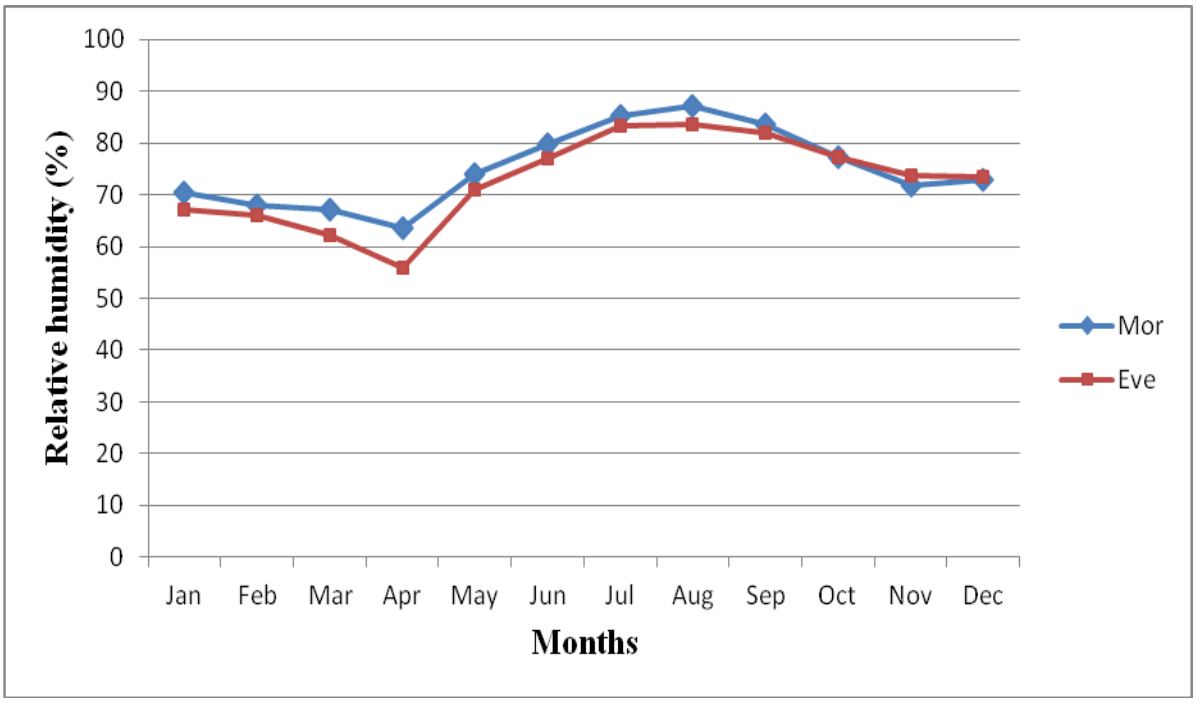

Figure 6: Average monthly relative humidity of morning and evening (2013-2017) at Phidim, Panchthar, Nepal. (Data source: DHM/GoVN)

3.1.3 Vegetation

The altitude of the study area ranged from 2300m to 3400m and characterized by two vegetation zones; Oak forest (2600m – 2800m) and broad leaved Broadleaf Deciduous forest (2800m – 3000m) (Pradhan, *et al*.,2001a). The Oak Forest is composed of *Schefflera impressa, Rhododendron* sp., *Quercus* sp., *Lithocarpus pachyphylla, Lithocarpus elegans, Magnolia campbellii, Litsea salicifolia, Litsea khasyana, Machilus edulis, Symplocos pyrifolia, Symplocos theifolia, Acer* sp., *Daphniphyllum himalayense, Symplocos ramosissima, Mahonia nepaulensis* and *Osmanthus suavis* while the most common shrubs and herbs found are *Arundinaria maling, Elastostema sessile, Fragaria nubicola, Daphne bholua, Rubus* sp., *Viburnum erubescens* and *Lyonia ovalifolia*. Broadleaf Deciduous Forest is dominated by *Betula utilis, Sorbus cuspidata, Acer* sp., *Leucosceptnum canum, Zanthoxylum armatum, Taxus baccata, Vitex heterophylla, Lindera pulcherrima, arboretum, Rhododendron falconeri, Pinus* sp., *Meliosma delleniaefolia* etc while the common shrubs and herbs are *Arundinaria maling, Arundinaria aristata, Vitex erubescense, Rosa sericera, Piptanthus nepalensis, Daphne bholua, Rubus* sp. etc.

3.1.4 Fauna

The major fauna present in Eastern Nepal (Panchthar, Ilam, Taplejung) includes Common Leopard (*Panthera pardus*), Clouded Leopard (*Neofelis nebulosa*), Himalayan Black Bear (*Solenarctos thibetanus*), Leopard Cat (*Prionaulurus benghalensis*), and Red Panda (*Ailurus fulgens*) (Kandel, 2009). In addition other common wild mammals present in the area are Assamese Macaque (*Macaca assamensis*), Barking Deer (*Muntiacus vaginalis*), Black Giant Squirrel (*Ratufa bicolor*), Giant Flying Squirrel (*Spelaeornis caudatus*), Golden Jackal (*Canis aureus*), Himalayan Civet (*Paguma larvata*), Himalayan Langur (*Semnopithecus entellus*), Himalayan serow (*Nemorhaedus sumatraensis*), Porcupine (*Hytrix indica*), Wild Boar (*Sus scrofa*), Yellow Throated Martin (*Martes flavigula*), etc. Important bird species found in this region are includes: Yellow Vented Warbler (*Phylloscopus cantator*), Rufous-thorated Wren Babbler (*Spelaeornis caudatus*), Spiny Babbler (*Tordoides nepalensis*), and Hoary-throated Barwing (*Actinodura nipalensis*) and Asian Fairy Bluebird (*Irena puella*) which is very rare in Nepal. Other bird species includes 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).

3.2 Materials

The scientific instruments and chemicals used during field survey and laboratory work were:

- GPS
- Compass
- Vernier caliper
- Binocular Microscope
- Digital camera for microscope
- Sodium hypochlorite (4%)
- Glycerine
- Staining chemical: gentian violet solution

3.3 Methods

3.3.1 Preliminary survey

A preliminary field survey was carried out during January, 2018 to identify the sampling sites. The survey was done by general observation of the potential habitat using existing trails. Additional informations about the habitat were collected from the secondary sources, semi structured questionnaires and informal interviews with local villagers, herders and hotel staff near the study area.

3.3.2 Field survey

Field survey was done during May, 2018 by using following methods;

3.3.2.1 Sampling Design

Altitudinal line intercept method (Sutherland, 1996) followed by Williams (2004) was used to collect fecal signs and reference plants. First transect was selected between the altitudes of 2,300 m and 2,500 m and second was between the altitudes of 2,500 m and 2,700 m and so on. In this way the last transcet was between the altitudes of 2,900 m and 3,100 m. The altitudinal interval of each transcet was 200 m and length ranged from 400 m to1,000 m. Transcets were traversed in east-west direction for the ease of walking in highly uneven topographic area.

Within each transect random sampling method was used to collect different parameters from the field. Quadrates were plotted in the areas that contained Red Panda's signs (scats, foot prints, resting sites, etc). Quadrates sized 10m × 10m for tree (plants above 3m height and 5cm DBH), 4m × 4m for shrub (woody plants below 3m in height), and 1m × 1m for herbs (plants up to 1m in height) were used. In each plot number of trees of each species as well as frequency of shrubs and herbs were recorded. The availability of each plant species recorded within the field was converted in terms of percentage. Then it was compared with its percentage of occurrence in diet.

3.3.2.2 Plant Collection

Different parts (leaves, twigs, fruits, flowers and bark) of potential food plants were collected which were later used for the preparation of reference slides. The plant species were labeled with their Nepali name. All the collected plant materials were preserved in herbarium press and brought to the Central Department of Botany for further identification and confirmation. The plant species were identified up to species level using the book Flora of Bhutan (Grierson and Long, 1983-2000).

3.3.2.3 Scat Identification and Collection

Scats of Red Panda were identified based on the shape, size colour and texture. Yonzon (1989) reported that scats of the Red Panda are spindle shaped, soft, moist, light green colored with average diameter of 19.2 ± 2.3 mm. About 25% of each fecal sample found within the transects were collected in polythene zip lock bags and labeled with GPS location. The samples were air dried in the field to remove moisture and prevent fungal growth. All the collected materials were brought to the laboratory of Central Department of Zoology, Tribhuvan University for further analysis.

3.3.3 Micro-histological Analysis

The micro-histological technique introduced by Baumgartner and Martin (1939) was used to determine the diet composition of the Red Panda. This method is based on microscopic recognition of undigested plant fragments present in fecal samples, which mainly include epidermal features of various plant groups (Metealf, 1960). This method involves preparation of reference plants and fecal slides and their interpretation**.**

3.3.3.1 Slide Preparation

The method introduced by Norbury (1988) was adopted to prepare the micro-histological slides. This method had been used by Singh (2015), Kunwar *et al.,* (2016) and Magar (2016) in Nepal. The plant samples were identified up to species level and then dried in the oven at 60 °C in the laboratory of the CDZ, TU. The dried samples were powdered separately through electric blender and the powder was sieved in mesh of size 1 mm to 0.3 mm. The powder remained on the 0.3 mm sieve was chosen as final reference sample for slide preparation. Same procedure was followed for fecal samples.

Each of 0.5 gm of powdered sample was taken in a Petri dish and bleached with 50 ml of 4% Sodium hypochlorite for 6-24 hours at room temperature to remove mesophyll tissues and to render the epidermis identifiable. The bleached contents were then rinsed with distilled water thoroughly in a sieve and then treated with few drops of staining substance-gentian violet solution for 10 seconds and again well rinsed. The stained fragments were mounted on standard microscope slides in a glycerin medium and covered with a cover slip. Both reference slides and fecal pellet slides were observed immediately after preparation at different magnifications; 4X, 10X and 100X with a compound microscope and each fragments were photographed using digital camera for microscope

(DCM510; USB2.0; 5M pixel, CMOS chip) in a laptop using software- ScopeTek Scope Photo; Version: x84, 3.1.615 (http://www.scopetek.com).

3.3.3.2 Slide Interpretation

At first the key features of the reference plants such as; structure, shape, size and arrangement of epidermal cells, stomata, vascular vessels, trichomes, etc. were photographed through 4X, 10X and 100X microscope. Then for each fecal sample, non-overlapping and distinguishable 20 fragments were observed moving the slide from right to left in the microscope. Each fragment of the fecal sample slide was identified by comparing it with the reference plants photographs.

3.4 Data Analysis

The plant fragments identified in the diet were classified into four major levels: 1. Functional group (F.G): a. bamboos, b. trees, c. herbs and d. mosses; 2. Broad Category (B.C.): a. monocots and b. dicots; 3. Family; and 4. species.

3.4.1. Diet Composition

Diet composition of the animal was expressed in terms of percentage of occurrence (O%) (Caavalini and Lovari, 1991).

$$\text{Percentage of occurrence}(O\%) = \frac{\text{Number of occurrence of each food}}{\text{Total number of fragments read}} \times 100$$

3.4.2 Niche Breadth

Levin's measure of Niche Breadth (Levins 1968) described by Krebs (1999) was used to evaluate the degree of selectivity of plant species by Red Panda. The measures indicate how uniformly resources are being utilized.

The equation is;

$$B = \frac{1}{\sum_{i=1}^{n} p_i^2}$$

Where, B= Levin's Measure of Niche Breadth, pi = Percentage of total samples belonging to species i (i= 1, 2..., n) n= total number of plant species in all samples.

Diversity was standardized to a scale of 0.0 to 1.0 by using Hurlbert's method (Krebs 1999).

$$Bs = \frac{B - 1}{n - 1}$$

Where, Bs = Levins's standardized niche breadth and
n = number of possible resource states

A high value of Bs indicates that the animal is generalized feeder and low value indicates that the animal is selective or specialized feeder.

3.4.3 Availability, Use and Preference of Food Plants

For the determination the food preference of Red Panda, availability of food plants in the study area was compared with its percentage of occurrence in diet. The availability of each food plant in each quadrate was measured in terms of percentage. Average of each food plant's availability percentage throughout the field was determined and it was compared with its percentage of occurrence in overall diet, which occurred through laboratory work**.**

3.4.4 Relative Importance Value

Relative Importance Value (RIV) of each plant species observed in the fecal sample was calculated using the formula described by Jnawali (1995) and Thapa and Basnet (2015).

$$RIV_x = D_x\sqrt{f_x}$$

Where, RIV = Relative Importance Value for species X

D_x = Mean percent of species X in fecal sample

f_x = Frequency of species in fecal sample

4. RESULTS

A total of 30 fecal samples were collected and analyzed using micro-histological technique. Among the collected plant samples 10 species (seven trees, two herbs, one herb) belonging to seven different families were identified. About 5.33 percent of the diet could not be recognized and categorized as unidentified. Micro-histological photographs showing different features (epidermal cell shape, size and arrangement, stomata, vascular vessels structure, shape of hairs and trichomes, crystal types, etc.) of the reference plants were prepared and compared them with fragments in the fecal remains through micro-histological technique.

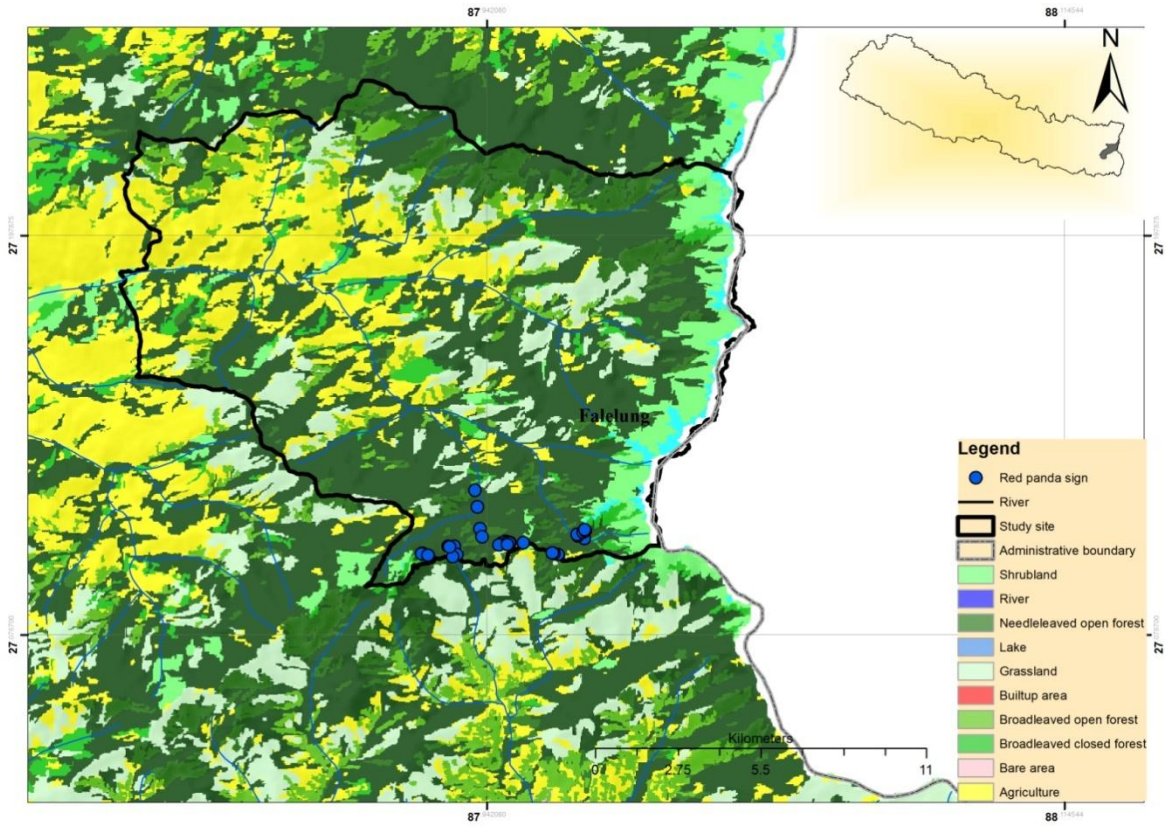

Figure 7: Map of study area (Sidin, Panchthar, Nepal) showing transects locations.

4.1 Diet Composition

A total of 600 plant fragments from 30 pellet samples were analyzed through micro-histological technique and 10 different plant species belonging to seven families were identified in fecal samples of Red Panda. Also some unknown plant species were found in the samples. Red Panda was found to be specialized feeder mainly feeding on bamboo (Table 1).

Table 1: Percentage occurrence of various plant categories (F.C. = Functional category; B.C. = Broad category; Family and Species) identified in fecal pellets of Red Panda in Panchthar, Eastern Nepal.

F.C.	B.C.	Family	Species	Fragments Read	% of Occurrence
Trees	Dicots	Rosaceae	*Sorbus cuspidate*	13	2.17
		Araliaceae	*Schefflera impressa*	2	0.33
		Sapindaceae	*Acer caudatum*	4	0.67
		Lamiaceae	*Vitex heterophylla*	3	0.5
		Lauraceae	*Litsea salicifolia*	2	0.33
			Litsea khasyana	1	0.17
		Ericaceae	*Rhododendron* spp	3	0.5
Shrubs	Monocots	Gramineae	*Arundinaria maling*	296	49.33
			Arundinaria aristata	239	39.83
Herbs	Dicots	Rosaceae	*Rubus* sp	5	0.84
Unidentified				32	5.33
Total				600	100.0

Through analysis, the Red panda was found to be dependent mainly on shoots, leaves and fruits of various plant species. The species found were; *Arundinaria maling, Arundinaria aristata, Sorbus cuspidata, Schefflera impressa, Acer caudatum, Vitex heterophylla, Litsea khasyana, Litsea salicifolia, Rhododendron* spp, *Rubus* sp along with few wings and appendages of unidentified arthropods.

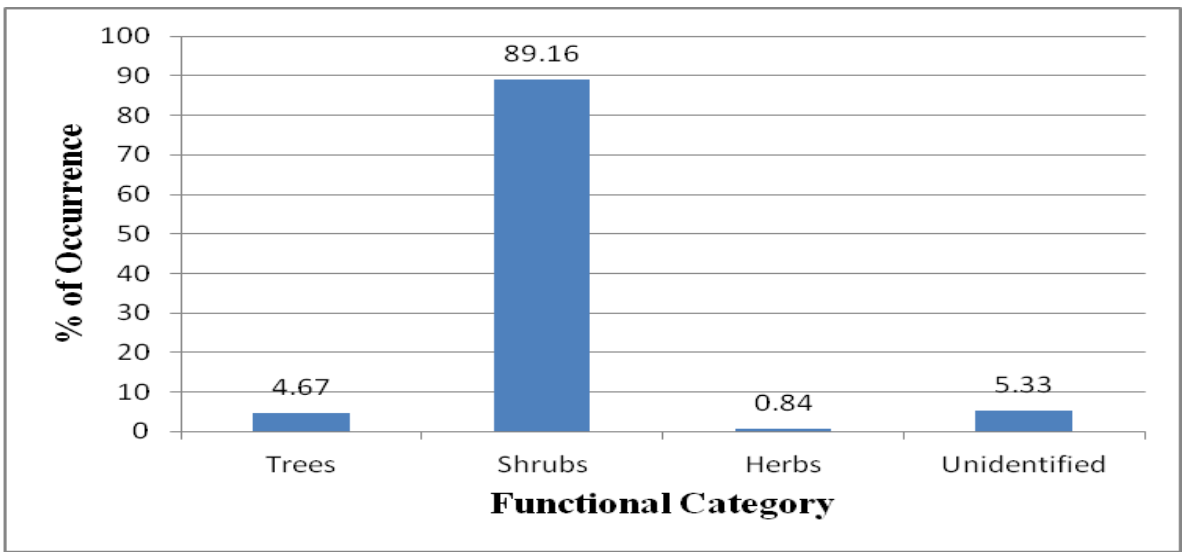

Figure 8: Percentage Occurrence of functional plant categories identified in the pellets of Red Panda in Panchthar, Eastern Nepal.

Shrubs of category bamboos contributed highest proportion (89.16%) of the diet of Red Panda followed by trees (4.67%) and herbs (0.84%). Likewise 5.33 percent of the dietary plants could not be identified (Figure 8).

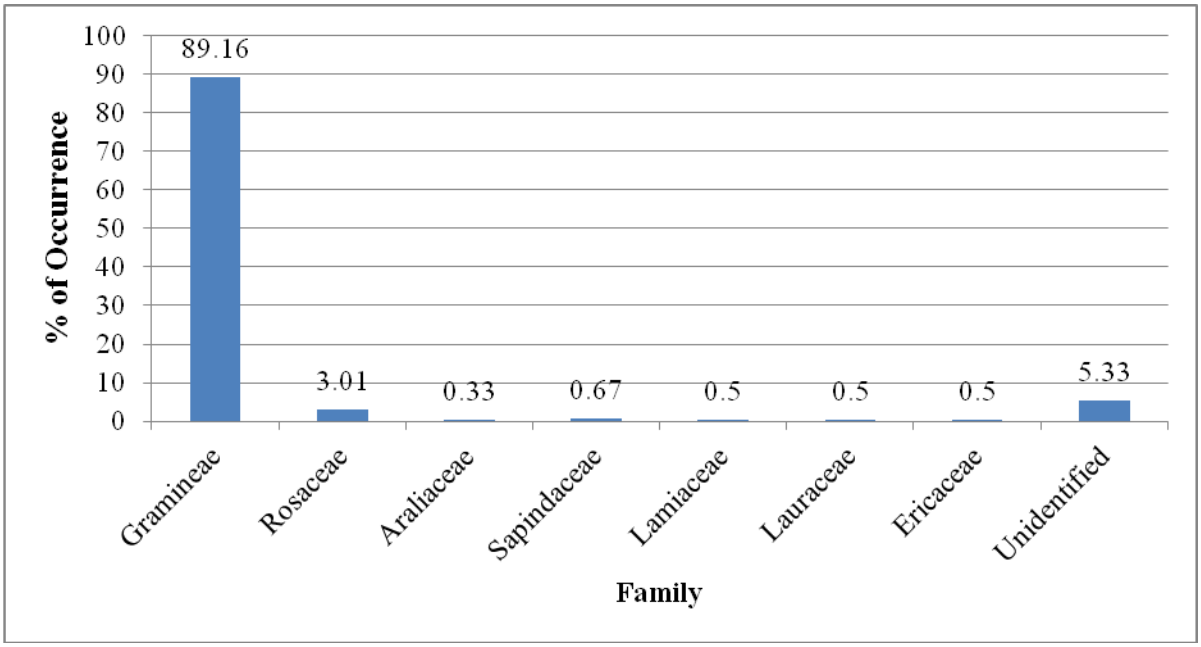

Figure 9: Percentage of occurrence of different plant families in diet of Red Panda in Panchthar, Eastern Nepal.

Among the seven families of plant consumed by Red Panda the Gramineae i.e. bamboos were consumed in highest proportion (89.16%) followed by Rosaceae (3.01%), Sapindaceae (0.67%), Ericaceae, Lamiaceae and Lauraceae (0.5%), Araliaceae (0.33%). While 5.33 percent of the overall diet remained unidentified (Figure: 9).

Among plant species identified in the faecal matter of Red Panda, two bamboo species *Arundinaria maling* (Malingo) (49.33) and *Arundinaria aristata* (Nigalo) (39.83%) contributed significantly in diet. Among the seven different tree species found in diet, *Sorbus cuspidata* (Tenga) was found in highest proportion (2.17%). Other tree species found were *Acer caudatum* (Bhale kapasi), *Vitex heterophylla* (Panchpate), *Rhododendron* spp (Laligurans), *Litsea salicifolia* (Pahele ghans), *Litsea Khasyana* (Lampate) and *Schefflera impressa* (Bhalu chinde). Only one herb i.e. *Rubus* sp. (Kande aaiselu) contributing 0.84 percent was found in the diet.

4.2 Niche Breadth

Standardized Levin's Measure of Niche Breadth (Bs) of food plants for the red panda was found to be 0.0706 (Table 2) indicating that red panda is a specialized feeder foraging on highly selected plant species.

Table 2: Incidence in number of samples (IN), Incidence in percentage (I%) and Levin's Measure of Niche Breadth (Bs) of different plant species identified in fecal samples (n=30) of Red Panda in Panchthar, Eastern Nepal.

Food plant Species	IN	I%	Bs
Arundinaria maling	29	96.67	0.0706
Arundinaria aristata	27	90	
Sorbus cuspidate	10	33.33	
Schefflera impressa	2	6.67	
Acer caudatum	4	13.33	
Vitex heterophylla	2	6.67	
Litsea salicifolia	2	6.67	
Litsea khasyana	1	3.33	
Rhododendron spp	3	10	
Rubus sp	4	13.33	
Unidentified	13	43.33	

4.3 Diet Preference

A total of seven trees, two shrubs and one herb species were recorded to be consumed by the Red Panda. Among the trees, *Sorbus cuspidata* has the highest contribution (2.17%) and lowest were *Schefflera impressa* and *Litsea salicifolia* (0.33%) in overall diet of the animal. Similarly, highly consumed shrub species was *Arundinaria maling* (49.33%) and one herb, *Rubus* sp. was found to be consumed only 0.84% in overall diet composition.

4.3.1 Trees

Seven trees were found to be consumed by the Red Panda. Comparison of the frequency of availability in the field and frequency of occurrence in diet clearly revealed that the Red Panda showed distinct preference in diet selection. Among the trees *Sorbus cuspidate* and *Acer caudatum* were found to be highly preferred by the Red Panda, while *Schefflera impressa; Litsea salicifolia*, *Vitex heterophylla*, *Litsea khasyana* were found to be used according to their availability in the area. *Rhododendron* spp were consumed in very low proportion than availability which indicates least preference of the animal towards the food plant (Table 3).

Table 3: Tree species preference in diet of Red Panda

S.N.	Species	Availability in field (%)	Occurrence in diet (%)	Preference
1	*Acer caudatum*	3.94	13.13	High preference
2	*Schefflera impressa*	3.76	7.33	Preference
3	*Rhododendron* spp	70.07	11.11	Least preference
4	*Litsea salicifolia*	4.37	7.33	Preference
5	*Vitex heterophylla*	6.16	10.11	Preference
6	*Sorbus cuspidata*	7.10	47.22	High preference
7	*Litsea khasyana*	4.6	3.77	Preference
Total		100.00	100.00	

4.3.2 Shrubs

Two shrub species were found to be consumed by Red Panda. Comparison of the frequency of availability in the field and frequency of occurrence in diet clearly revealed that the Red Panda showed high preference towards the both *Arundinaria maling* and *Arundinaria aristata*. (Table 4).

Table 4: Shrubs species preference in diet of Red Panda

S.N.	Species	Availability in field (%)	Occurrence in diet (%)	Preference
1	*Arundinaria maling*	59.15	55.24	High preference
2	*Arundinaria aristata*	35.33	44.57	High preference
	Total	100.0	100.0	

4.3.3 Herbs

Only one herb (*Rubus* sp.) was found to be consumed by the Red Panda. Contribution of the *Rubus* sp. in overall diet composition of the animal was found to be 0.84 percent.

4.4 Relative Importance Value of Species

Among the various food species, highest Relative Importance Value (RIV) was found of *Arundinaria maling* (848.70) followed by *Arundinaria aristata* (615.76), *Sorbus cuspidata* (7.82) and *Rubus* sps (1.88) (Table 4.3). Other species had very low RIV in red panda's diet. These RIV of various plant species may show the relative preference of the animal for its diet supplement.

Table 5: Relative importance value (RIV) of different plant species identified in fecal samples of Red Panda in Panchther, Eastern Nepal. D = Mean percent of species in sample, F = Frequency of fragments of species in sample

Food plant Species	F	D	RIV
Arundinaria maling	296	49.33	848.70
Arundinaria aristata	239	39.83	615.76
Sorbus cuspidate	13	2.17	7.82
Schefflera impressa	2	0.33	0.47
Acer caudatum	4	0.67	1.34
Vitex heterophylla	3	0.5	0.87
Litsea salicifolia	2	0.33	0.47
Litsea khasyana	1	0.17	0.17
Rhododendron spp	3	0.5	0.87
Rubus sp	5	0.84	1.88
Unidentified	32	5.33	

5. DISCUSSION

Descriptive accounts of diet composition and dietary niche breadth of Red Panda have been analyzed in different protected areas of Nepal (Yonzon and Hunter, 1991a; Karki, 2009; Panthi *et al.*, 2012; Sharma *et al*., 2014; Thapa and Basnet, 2015); however, this study shows the similar dietary patterns and consumption patterns for specific plant species in area outside of the PAs. In-spite of differences in the species of bamboo availability and consumed by Red Pandas across their range (*Thamnocalamus* sp.: Yonzon and Hunter, 1991a; Karki, 2009; Sharma *et al*., 2014; Thapa and Basnet, 2015; *Sinarundinaria fagiana* and *Fargesia spathecea*: Reid *et al*., 1991; *Bashania faberi*: Zhang *et al*., 2009; *Arundinaria* sp.: Pradhan *et al*., 2001b; Panthi *et al.,* 2012), the dependency in bamboo species probably suggests their co-evolutionary association with bamboo species.

5.1 Diet Composition

Micro-histological analysis of fecal matter of Red Panda clearly revealed that *Arundinaria maling* contributed the significant (49.33%) portion of the diet, followed by *Arundinaria aristata* (39.83%). The *Sorbus cuspidata, Acer caudatum, Schefflera impressa, Vitex heterophylla, Litsea salicifolia, Litsea khasyana, Rhododendron* spp. and *Rubus* sp. provided very little portion of the diet in comparison to the *Arundinaria* species like elsewhere (Pradhan *et al*., 2001b; Sharma *et al*., 2014; Thapa and Basnet, 2015).

Yonzon and Hunter (1991a) reported the Panda's diet was dominated by *Thamnocalamus* sp. up to 54–100% in LNP, Nepal. Other supplementary food items were found to be *Sorbus cuspidata, R. arboreum,* mushroom, etc. Reid *et al*., (1991) reported that the Panda is highly dependent upon *Sinarundinaria fagiana* and shoots of *Fargesia spathecea* in Wolog Nature Reserve, China. Pradhan *et al*., (2001b) reported that *Arundinaria* sp. as highly consumed bamboo species. Overall result of showed *Arundinaria aristata* (45%), *Arundinaria maling* (35%) and various fruits as supplementary food especially in post-monsoon season. The current study also showed the highest availability of the *Arundinaria* sps. in diet but proportion of the two bamboo species were just opposite of Pradhan *et al*., (2001b). The current study showed *Arundinaria maling* (49.33%) and *Arundinaria aristata* (39.83%). The contradiction may be due to the high availability of a particular species in the study area. In the recent study we could not found fruits in noticeable proportion, probably due to the season we conducted study, as fruiting occur only during post-monsoon season. Zhang *et al*., (2009) reported that the animal almost exclusively fed on *Bashania faberi*, in China. Karki (2009), suggested that the Red Panda feed on various six plant species with *Thamnocalamus aristatus* highest proportion. Panthi *et al.,* (2012), studied the summer diet of the animal and reported *Arundinaria* sp. (81.7%), as the dominant diet in scat of the Red Panda with *Acer* sp., *B. utilis*, and lichen also frequently present diet species. Sharma *et al*., (2014), observed 12 plant species in diet of the Red Panda and leaves and shoots of *Thamnocalamus sp*. were the major. They did not found any animal matter in the scat of the animal. In this sense the current study's result is similar to Sharma *et al*.,

(2014), as no any animal remains were found but only some unidentified Arthropods' parts were found. Thapa and Basnet (2015), suggested eight plants species were consumed by Red Panda with *Thamnocalamus aristatus* highest proportion throughout the year. Some of the supplementary food species suggested such as; *Rubus* sp, *Sorbus cuspidata Rhododendron* spp, *Acer caudatum* etc were similar to the current study.

Out of the two bamboo species encountered in the study area, *Arundinaria maling* was found to be consumed in the highest proportion (49.33%). This high consumption may be probably due to high availability of the *Arundinaria maling* than the *Arundinaria aristata* in the area. Among the seven tree species found to be consumed, *Sorbus cuspidata* (2.17%) of the family Rosaceae was the most preferred. Thapa and Basnet (2015), reported *Sorbus cuspidata* contributed about 5 % of the summer diet of the animal in LNP. Other tree species; *Acer caudatum, Rhododendron sps, Vitex heterophylla, Litsea salicifolia, Schefflera impressa, Litsea salicifolia* were found to be consumed in very little portion (> 1%) in Sidin, Panchthar. Only one herb species i.e. *Rubus* sp. of the family Rosaceae was found to be consumed by the animal and it contributed 0.84 % of the diet.

In overall, bamboo was found to be the most important food item for Red Panda, contributing 89.16 percent of the overall diet. Previous studies had shown this percentage ranged from 50-100 percent; 54-100% by Yonzon and Hunter (1991a), 89.9% by Wei *et al,.* (1999a), 80% by Pradhan *et al*., (2001b), 81.7% by Panthi *et al.*, (2012), 80-100% by Sharma *et al*., (2014), 91.25% by Thapa and Basnet (2015). All previous studies done on diet of the Panda till date had shown bamboo as major food item. Difference found is only the types of the bamboo species. It is difficult to say how particular the Pandas are about selecting the bamboo species (Pradhan *et al*., 2001b). The unidentified percentage was 2.5 percent in the study of Panthi *et al.,* (2012), 4.96 percent in the study of Thapa and Basnet (2015). In-vitro digestibility as well as selection of plant parts by the animal greatly influences the results of micro-histological analysis (Vavra and Holechek, 1980). Better the digestive system of the animal, better the digestion of the ingested food and greater the difficulty in identification of the food items. The digestive system of the Red Panda is not well developed (Oftedal *et al*., 1989), which may results in improper digestion of the foods, especially stem parts. This helps in little easier identification of food items. However, as it also consumes fruits, flowers and fresh leaves, which are easily and properly digested and could not be identified. So some food items remained unidentified. In the study of the diet composition of the Red Panda, due to ill-developed digestive system and not proper digestion, the percentage of unidentified plants usually does not remain high as in case of other animals having high digestion rate like; four horned antelopes. Also, sometimes the biasness subjected to micro-histological analysis, like sample preparation (Vavra and Holechek, 1980), poor training of technician (Holechek and Gross, 1982) and differential digestibility of diet components (Holechek *et al.*, 1982) may have influenced in identification of diet items.

5.2 Niche Breadth

Niche breadth is a parameter that measures in how much extent the animal uses its surrounding resources; habitat, food etc. Most importantly, body size of a particular animal determines its metabolic rate, food requirement and also niche breadth as large bodied animals have higher food requirement since they have higher cost of maintenance and production (Geist, 1974). In the present study niche, breadth of the panda was calculated 0.0706, which is low value as niche breadth ranges between 0-1 according to Krebs, 1999. The result suggested that the animal is highly specialized and it uses selected food items and habitats for its survival. Previous studies Yonzon (1989), Thapa and Basnet (2015) had also suggested narrower niche breadth of the Red Panda. Having narrower niche breadth is one of the most important reasons of declining the Red Pandas population day by day. It can be said this in the sense that as the panda uses very limited resources for its survival, when that resources become scarce survival of the Panda may be in danger. So it may be true that wider the niche breadth, lower the risk of extinction and narrower the niche breadth, higher the risk of extinction.

5.3 Diet Preference

Plant species differ in composition of protein and fibre contents which influences animals' food choice (Klaus-Hugii *et al.*, 1999) and their digestion period. Diet selection and preference of different animals are found to be different as their body structure and internal organ systems are also different. Sometimes, it may be irrelevant to categorize the food items of a particular animal as preferred or nonpreferred only through faecal analysis as the digestibility of different food plants may be variable. In spite of this, due to the lack of any scientific practical method for determining the food preference of wild animals, faecal analysis method has been applied in this study to determine the diet preference of the animal. In the current study, seven tree species were found to be consumed by the animal. *Sorbus cuspidata* and *Acer caudatum* were found to be the most preferred species among the trees. Similarly, two shrub species belonging to bamboo category were found to be consumed. The both species of genera *Arundinaria* were highly preferred by the animal. Only one herb species, *Rubus* sp. was consumed by the animal. As the study was conducted during the month of May food preference of Red Panda determined through comparison of availability percentage and use based on the fecal analysis indicates only the spring season’s preference of foods.

Previous studies; Yonzon and Hunter (1991a), Pradhan *et al*., (2001b), Zhang *et al*., (2009), Karki (2009), Panthi *et al.*, (2012), Sharma *et al*., (2014), Thapa and Basnet (2015) had reported different bamboo species as the preferred food plant of the Red Panda in different study areas. The recent study also confirmed the bamboo (*Arundinaria* spp.) as the most preferred and major food item for the animal. So it may be said that as the animal prefers the subtropical, temperate, sub alpine and alpine forest with dense bamboo-thicket understory (Yonzon and Hunter, 1991a; Pradhan *et al*., 2001; Sharma and Belant, 2009), it consumes any species of bamboo in high proportion that is available within its habitat.

6. CONCLUSION AND RECOMMENDATIONS

The study conducted in Sidin area of Panchthar district on May, 2018, showed that the Red Panda feeds on 10 plant species belonging to seven different families which were confirmed through micro-histological analysis of faecal samples. It feeds on highly selected plant categories in various proportions. Altogether, seven trees, two shrubs belonging to bamboo category and one herb were found as contributing foods of the Red Pandas' diet. The dietary plants were *Arundinaria maling, Arundinaria aristata, Sorbus cuspidata, Schefflera impressa, Acer caudatum, Vitex heterophylla, Litsea salicifolia, Litsea khasyana, Rhododendron* spp and *Rubus* sp. Besides these, some wings and appendages of unidentified arthropods were observed in few faecal samples, which may be consumed along with the food plants. Bamboo was found to be consumed in high percentage; about 90% of the overall diet composition, indicating bamboo as the major food item. Niche breadth value was found to be low which concluded that the Red Panda is highly selective in diet and has specialized feeding behavior. Among the consumed food plants, *Arundinaria maling* was found to be highly consumed followed by *Arundinaria aristata*. The result indicates that the *Arundinaria* spp. as highly preferred food item of the animal. Similarly, *Sorbus cuspidata* and *Acer caudatum* were found to be highly preferred tree species whose proportions in diet were high in comparison of their availability in the field. *Rhododendron* spp were consumed in very low proportion in comparison to their availability in the field, indicating least preference of Red Panda towards *Rhododendron* spp.

Based on the study, following recommendations are put forward.

- Knowledge on feeding ecology is very important for the protection and management plan so detailed food habit studies of the species of whole year should be conducted in Sidin, Panchthar, Nepal and other landscapes too.
- Feeding niche overlap of the species with other wild as well as domestic animals should be studied in detail.
- Nutritional composition of the dietary plants should be studied in detailed through which dietary preference of the animal should be confirmed.

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PHOTOGRAPHS

I. Photographs from study area

1: Red Panda habitat area in Panchthar, Eastern Nepal 2: Red Panda habitat area

3: Habitat dominated by *Arundinaria* spp. 4: Tree hollow used by Red Panda as nest

5: Timber collected for making Goth 6: Chauri Goth inside Red Panda habitat

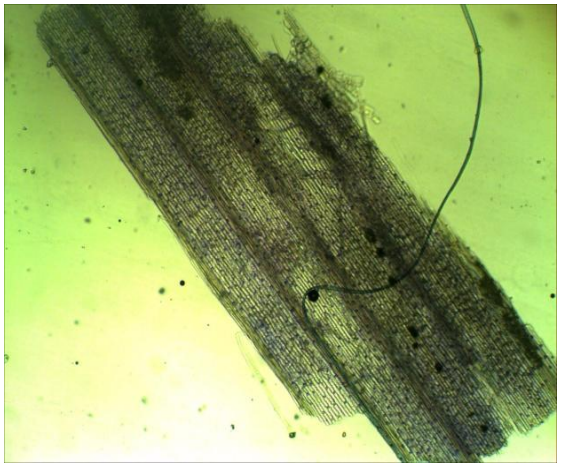
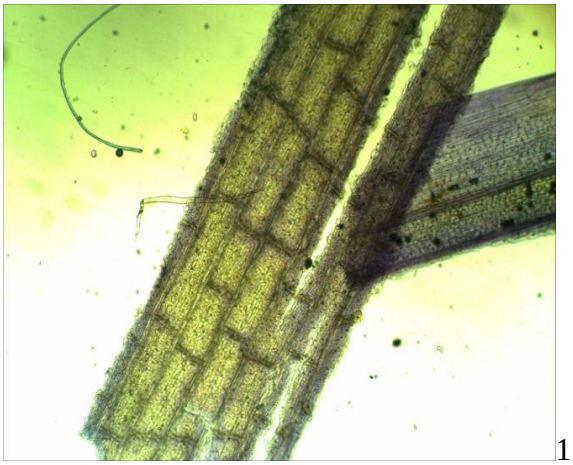
7: Scats of Red Panda on rock

8: Scats of Red Panda on *Magnolia campbellii* tree

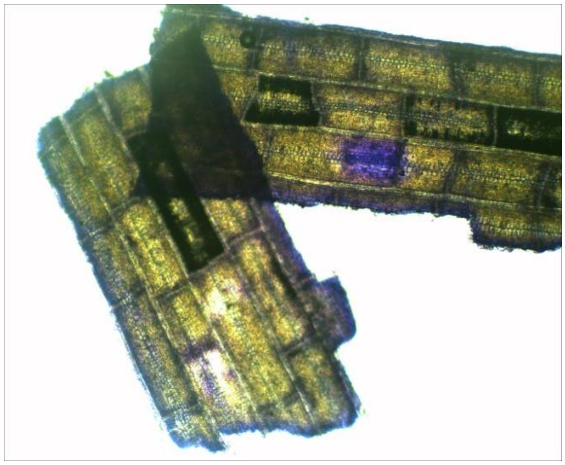
9: Samples and data collection

10: Quadrate sampling

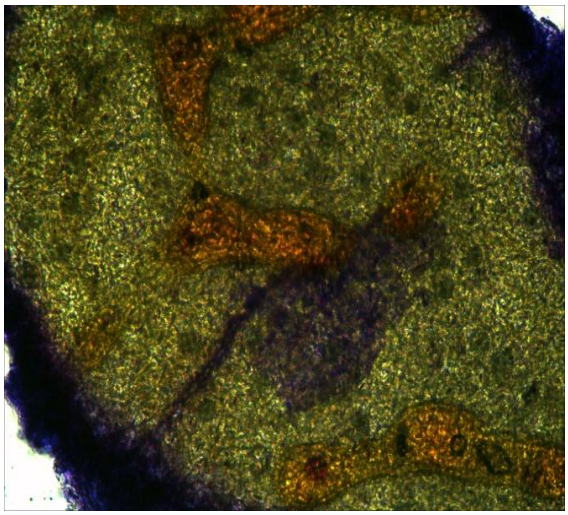
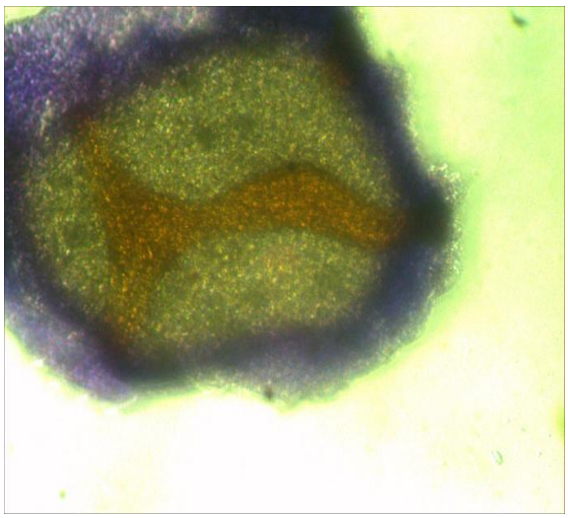
II. Histological photographs of major food plants of Red Panda in Panchthar, Eastern Nepal

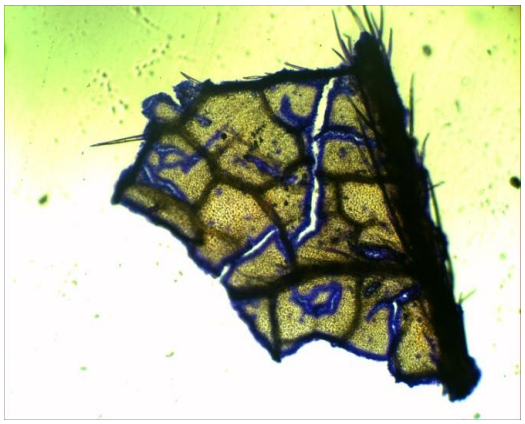
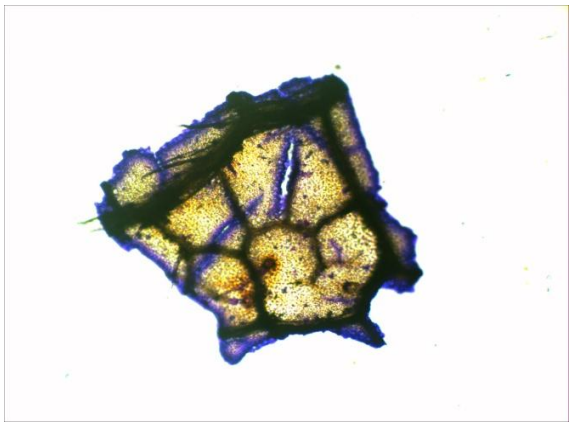
1: *Arundinaria maling* (Malingo)



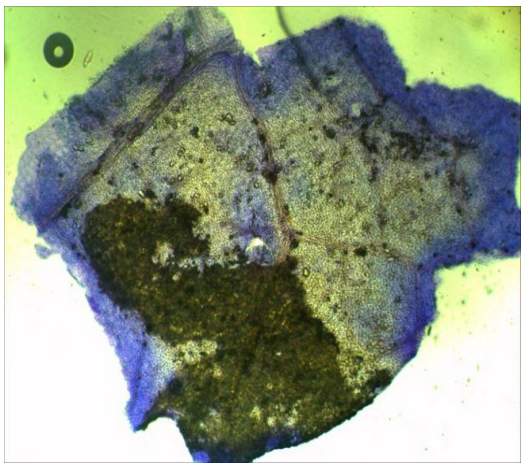
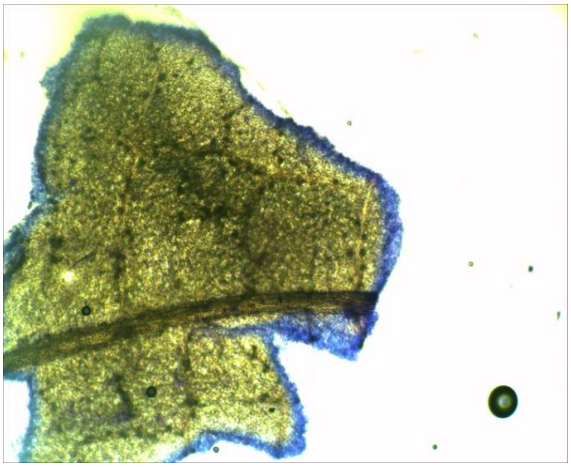

2: *Arundinaria aristata* (Nigalo)

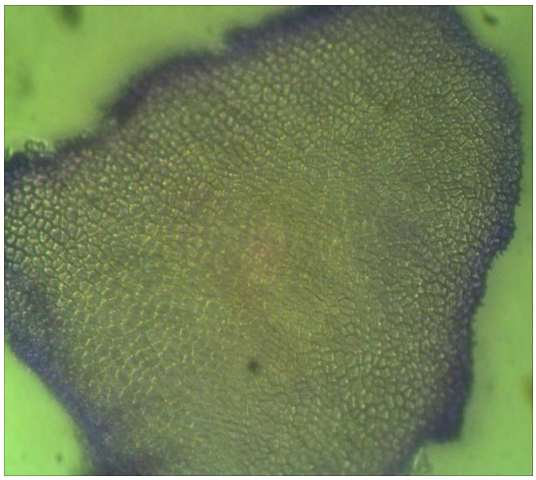
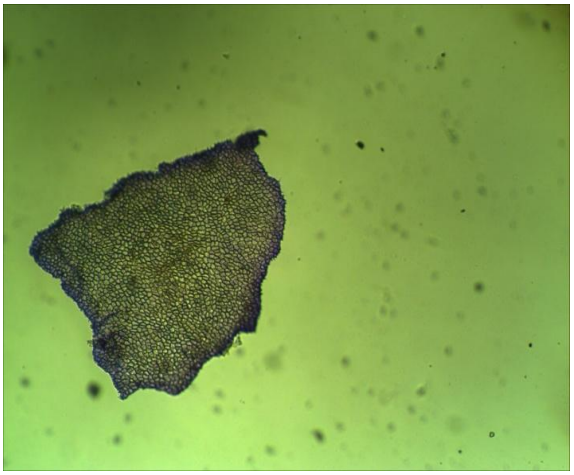
3: *Schefflera impressa* (Bhalu Chinde)

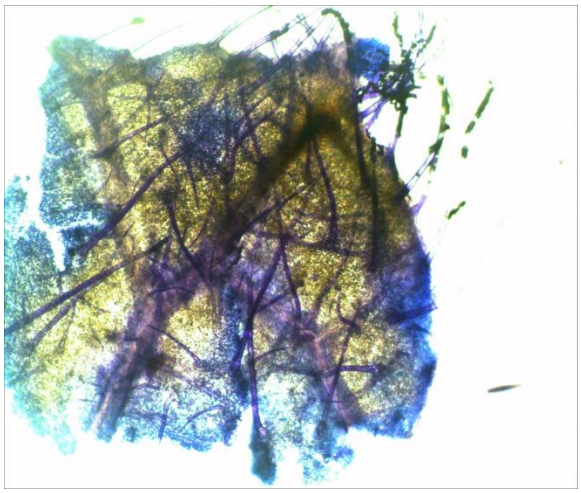
4: *Acer caudatum* (Bhale Kapasi)

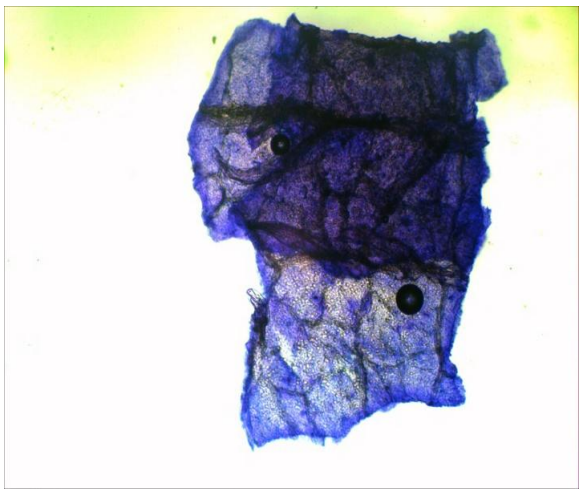
5: *Litsea salicifolia* (Pahele Ghans)

6: *Rhododendron* sp.(Laligurans)



7: *Rubus* sps (Kande Aaiselu)



8: *Vitex heterophylla* (Panchpate)