THE ECOLOGY OF PIKA (*OCHOTONA* SPECIES) AT LANGTANG NATIONAL PARK AS AN INDICATOR OF CLIMATE CHANGE

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BY

NARAYAN PRASAD KOJU

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DECLARATION

This thesis entitled **“The Ecology of Pika (*Ochotona* species) at Langtang National Park as an Indicator of Climate Change”** submitted to the Central Department of Zoology, Institute of Science and Technology (IOST), Tribhuvan University, Nepal for the award of the degree of Doctor of Philosophy (PhD), is a research work carried out by me under the supervision of Associate Prof. Dr Mukesh Kumar Chalise, Central Department of Zoology, Tribhuvan University and by Prof. Dr Randall C Kyes, Department of Psychology, University of Washington, USA.

This research is original and has not been submitted earlier in part or full in this or any other form to any University or Institute, here or elsewhere, for the award of any degree.

Narayan Prasad Koju

Reg. No17/ 2067-068

RECOMMENDATION

This is to recommend that **Narayan Prasad Koju** has carried out research entitled **"The Ecology of Pika (*Ochotona* species) at Langtang National Park as an Indicator of Climate Change"** for the award of Doctor of Philosophy (PhD) in **Zoology** under our supervision. To our knowledge, this work has not been submitted for any other degree.

He has fulfilled all the requirements laid down by the Institute of Science and Technology (IOST), Tribhuvan University, Kirtipur for the submission of the thesis for the award of Ph.D. degree.

Dr. Mukesh Kumar Chalise

Supervisor

Associate Professor

Central Department of Zoology

Tribhuvan University

Kirtipur, Kathmandu,

Nepal

Dr Randall C Kyes

Co-Supervisor

Professor

Department of Psychology

University of Washington (UW)

Seattle, WA, USA

September 2014

Phone No.: 01-4331896

TRIBHUVAN UNIVERSITY

CENTRAL DEPARTMENT OF ZOOLOGY

Kirtipur, Kathmandu

Nepal

Date: 10/ September/2014

LETTER OF APPROVAL

On the recommendation of Associate Prof. Dr **Mukesh Kumar Chalise** and Prof. Dr **Randall C Kyes**, this PhD. thesis submitted by **Narayan Prasad Koju** entitled **"The Ecology of Pika (*Ochotona* species) at Langtang National Park as an Indicator of Climate Change"** is forwarded by Central Department Research Committee (CDRC) to the Dean, IOST, TU.

Nov. 2, 2014

Dr Ranjana Gupta
Professor, Nepal
Head of Department
Central Department of Zoology,
Tribhuvan University
Kirtipur, Kathmandu

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ABSTRACT

Pikas are small mammal related to rabbit and hare that inhabit in rocky talus field in higher elevated alpine area. The Himalayas are only habitats of pika in Nepal. The study was carried out in transect of 53 km length and 200 m wide along the trails in two routes of Langtang National Park (LNP), Nepal from 2011 to 2014. Total fifty permanent quadrats of 50m x 50 m were plotted to study pika abundance and their behaviour in LNP. The observation was done for six times in different seasons. Within these quadrats, small quadrats of 20m x 20m were used to calculate tree, 5m x 5m quadrat for shrub and 1m x 1m for ground vegetation. The behaviour in 459 hours were recorded by focal scan sampling methods at interval of one minute. Grooming, musing, calling, feeding, foraging, chasing, resting inside burrow and galloping behaviour were observed as general behaviour and some special behaviour like mate (mounting), drinking water, defection of pellets, parental care were also recorded. Camera traps were used to record nocturnal behaviour, and Spring traps and Sherman traps were used to capture the pikas. Six most consumed (in frequency) plants were collected from different elevations. Nutrients like protein, Calcium, Phosphorus, Potassium, Total ash, moisture contain, Cellulose, Hemi-cellulose, Acid Detergent Lignin and Neutral detergent fiber were analyzed from those forage plants. Meteorological data of maximum temperature, minimum temperature, humidity and rainfall were analyzed that were collected from Department of Hydrology and Meteorology (DHM), Kyanging (3900m) station for 1983 to 2012. Eighteen temperature data loggers (DS1921G Thermochron iButtons) were installed in pika habitat at 200m altitudinal gradient. 1-Wire Drivers X86 software was used to download data from iButtons. Statistical analysis was done using Excel, R software and SPSS. GIS was used for mapping habitat and population of different pika species.

Only Large eared pika (*Ochotona macrotis*) and Royle's pika (*Ochotona. roylei*) were found in Langtang National Park during observation. They both have broadly similar morphology and use same habitat. The average body length *O. roylei* was 138.5 ± 0.64 mm and *O. macrotis* 152± 1.08mm. Habitat of pikas was categorized into three parts: forest, subalpine and alpine. During six field works, 674 pikas were observed. The population density of *O. roylei* was 4.8 /ha in forest and its edge area, 12.13/ha in subalpine area and

7.86/ha in alpine talus area. The *O. macrotis* had the population density 8.8/ha in subalpine area and 10.47/ha in talus alpine area. There was no significant relation between population distribution of pikas and their age category in subalpine area and alpine area but population density of *O. roylei* was significantly less (p value=0.014) in forest and its edge. Similarly, there was no significant difference between behaviour of adult *O. macrotis* and adult *O. roylei*, and with their respective juveniles but the seasonal behaviour was significantly different in both the species (p value=0.011).

In the study area, there were 65 plants species as ground vegetation. Pikas consumed 58 plants species. Fifteen species of plants were consumed in all four habitats, twenty-four species of plants were consumed by pikas in three habitats, three species of plants were consumed in two habitats and sixteen species of forage plants and their parts were consumed only in one habitat. Pikas showed the characters of coprophagous as well as geo-phagous. Pollutants especially plastic, paper, clothes, bottles, used batteries and other non-degradable wastes are affecting activities of pikas in Gosainkunda region.

The mean minimum temperature of Langtang National Park was increasing significantly in all seasons and months but mean maximum temperature had no significant change with time. The temperature of mid elevation of the study areas (3300 m to 3600 m) was almost constant. The temperature inside the burrows in these areas was cooler in hot summer and warmer in cold winter, and seems favorable for pika's survival. The temperature of higher elevation (above 3900 m) was warmer than lower elevation in summer and very colder in winter. There was 0.64^0C/100 m change in temperature from elevation of 3000 masl to 3500 masl. Similarly, the change in temperature were 0.46^0C/100 m from 3500 masl to 3980 masl and 0.453^0C/100 m from 3980 masl to 4600 masl. Pikas in Langtang were encountered not below 3000 m; this is 200m elevation above in the interval of two decades, indicating that they have either migrating upward or locally extinct at reported lower elevation. The number of days with temperature less than -5^0C is increasing in winter, thus, pikas in Langtang National Park, Nepal are under threat of acute cold stress caused by increase in mean minimum temperature in reference to climate change.

LIST OF ACRONYMS AND ABBREVIATIONS

ADF	Acid detergent fibre
ADL	Acid detergent lignin
AM	Ante meridian
ANOVA	Analysis of variance
CA	Conservation area
CP	Crude protein
DHM	Department of Hydrology and Meteorology
DNPWC	Department of National Parks and Wildlife Conservation
GPS	Global Positioning System
HC	Hemi-cellulose
IB	Inside burrow
IVI	Important value index
KWLS	Kedarnath Wildlife Sanctuary
LNP	Langtang National Park
masl	meter above sea level
Mya	Millions Year ago
NARC	Nepal Agricultural Research Council
NAST	Nepal Academy of Science and Technology
NDL	Neutral detergent lignin
NEc	Net energy consumption
NP	National Park
OM	Organic matter
PM	Post meridiem
RA	Relative abundance
RF	Relative frequency
RVF	Relative food value index
SPSS	Statistical Package for the Social Sciences
TDN	Total digestive nutrient
USSR	Union of Soviet Socialist Republic

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CHAPTER 1

1. INTRODUCTION

1.1. General Introduction

1.1.1 Feature of pika

The name pika originated from the Tungus of Siberia who attempted to mimic the call "peeka" of the local pika species and the generic name of *Ochotona* is derived from the Mongolian name for pikas: "ogdoi" (Macdonald, 2001). Systematically the pikas are a novel group, the living representatives of *Ochotona* form a monotypic genus within the family Ochotonidae, which was clearly differentiated from the other lagomorphs as early as the Oligocene (Dawson, 1967). All species of *Ochotona* are remarkably homogeneous in general morphology and body mass (Formozov, 1981). Himalayan pikas are small mammal related to rabbit and hare that inhabits in rocky talus field in alpine area (Kawamichi, 1968; Kawamichi, 1971a). The word pika is used for any member of the Ochotonidae, a family within the order of lagomorphs, which also includes the Leporidae (rabbits and hares).

Pikas are uniform in size with body mass ranging generally from 150g to 200g among species. There is little sexual dimorphism in pikas (Hoffmann and Smith, 2005). Pikas are reddish brown fur with pale band over the nape, the winter coat is similar, but may shows traces of rufous colouration (Smith et al., 1990). Its body length range from 15 – 20 cm and the diameter of head of 7 cm are found at 2800 m to 5000 m (Fedosenko, 1974; Formozov, 1981). They are small, oval shaped animals with prominent round ears and without external tail. The hind limbs are not appreciably longer than the fore limbs, and the hind feet are relatively short among lagomorphs. Male pika do not possess a scrotum or a baculum; female do not possess a vulva (Duke, 1951). Female have three pairs of mammae: one pectoral, one abdominal and one inguinal which do not enlarged greatly during lactation (Smith, 1981). There are five toes on the front feet and four on the hind feet. Soles of the feet are densely furred except for small black naked pads at the end of the toes. It has dental formula with I 2/1, c 0/0, p 3/2, m 2/3, total 26 (Smith and Weston, 1990). Pikas are frequently active during hours of dawn and dusk (Kawamichi, 1971b; Koju et al., 2012a), Nocturnal behaviour of pikas were not recorded till now (Koju et al., 2012b). Pikas are generalist herbivore and have high energetic demands than other mountain mammals because they don't hibernate so they make multiple trips per hour to collect vegetarian during summer seasons (Beever et al., 2003) that feed instantly as well as stored for winter. Their daily caloric intake is equivalent to filling their stomach nine times in a day. Food intake is found to increase during pregnancy and lactation period (Smith and Weston, 1990). Pika exhibits running, leaping, musing, intake and transport of food and calling as general behaviours but they don't exhibit high calls around Gosainkunda area in winter (Kawamichi, 1968). Pika makes two types of call - the long call Chirrr…rrr and the short call 'chi chi; they often make while musing on large rocks or during chasing each other. However, significance of calling is still unknown (Koju et al., 2012b)

The distribution of pika directly depends on the availability of forage plants species (Kawamichi, 1968; Bhattacharya et al., 2009). Pikas forage on various plant species.Koju et al. (2011) reported 42 plants species consumed by pika in Gosainkunda region during rainy season. Those contain herbs, shrubs and grasses along with their flower and fruits.Khanal et al. (1999) reported that 33 plant species accumulated in its hay piles in western part of Nepal. They spend around 23-25 percent of external time budget in feeding. Feeding is of two types: in rainy season feeding instantly and collecting food for hay pile to utilize in winter (Koju et al., 2013). The breeding season of pika starts from the late spring to late summer. Its average litter size is 3(Abe, 1971). They are solitary animals and shows partial parental character during rainy season (Koju et al., 2012c)

1.1.2 Pikas in the world

Pikas are endemic to the Holarctic realm (Feng et al., 1986), some are extending to northern Oriental realm (Smith et al., 1990; Hoffmann and Smith, 2005; Reese and Roles, 2014). Thirty species of pikas are distributed throughout the world. All thirty species of pikas are divided into three groups according to their habitat preference as Northern pika, shrub-steppe pikas and Mountain pika (Yu et al., 2000 Hoffmann and Smith, 2005 Smith and Xie, 2008). Pikas occupy one or another of two discretely different habitat types: 1) non-burrowing talus dwelling species; and 2) burrowing steppe- forest- and shrub-dwelling species (Kawamichi, 1971a; Smith et al., 1990). A few are intermediate species, those burrowing species which sometimes occupy talus or rock habitat but which also may occur in vegetated habitat devoid of rocks (Formozov, 1981; Hoffmann and Smith, 2005).

The species of *Ochotona* in Eurasia occur in open Gobi, at alpine heights above forest levels in the western Chinese highlands (Qinghai-Tibet Plateau) and the Himalayas, as well as at their vicinities (Feng et al., 1986). The species in America are only distributed in the northwest (Smith et al., 1990). Among these thirty species, *Ochotona roylei* is native to the Oriental, *Ochotona collaris* and *Ochotona princeps* are Nearctic native and remaining 27 are Palearctic native. China has the highest diversity of pikas with twenty four species (Smith and Xie, 2008; Reese and Roles, 2014), eighteen of them are concentrated in the Tibet (Qinghai-Xizang) Plateau and adjacent areas.

1.1.3 Distribution of pikas in Nepal

The species of pikas have been reported from an elevation 2650masl (Kawamichi, 1971b) to 6126masl (Thomas and Hinton, 1922). The Himalayan pika resides from 2500m to 5000m (Tak and Lamba, 1985)throughout Nepal. It has been recorded from mountainous areas within the habitat range of Rhododendron and Oak Forest, Fir and Hemlock Forest, Rhododendron and Juniper Forest to Shrubby and alpine meadows. Pika were seen in agricultural fields, Kharkas (rangelands and pasturelands), and steep slopes to igneous rocks (Kawamichi, 1968). They are reported from Sagarmatha National Park, Langtang National Park, Rara National Park, Annapurna Conservation Area, Makalu Barun National Park and mountain conservation areas (Shrestha, 2003). Khanal et al., (1999) reported them from Kalikot, Bajura and Ramaroshan of Achham. Koju and Chalise (2013) reported pika's around Api Nampa Conservation Area (ANCA), Nepal. Five species of pikas have been reported from Nepal namely *Ochotona curzoniae*, *O. macrotis*, *O. nubrica*, *O. roylei, O. thibetana* (IUCN, 2010).

The pika species recorded for Nepal:

***Ochotona curzoniae* (Hodgson, 1858):** *Ochotona. curzoniae* is a burrow-dwelling species of pika (Yu et al., 2000; Smith and Xie, 2008). This species occurs in high alpine desert, steppe and meadows inhabits at elevations of 3200 to 5300 masl (Smith et al., 1990). *O. curzoniae* is exclusively an herbivore. This species of pika is considered a highly social animal (Smith and Xie, 2008). It is predominantly a diurnal species. The breeding season for this species extends from April, possibly into late August (Smith et al., 1990). It has three to five litters per year with two to eight young per litter (Smith and Xie, 2008). Young become reproductively active at the immediate summer of their birth (Smith and Gao, 1991). Generation length is estimated to be 1.2 years for *O. curzoniae* (Dobson et al., 1998). Body length is 14.0-19.2 cm. *O. curzoniae* is a keystone species of the Tibetan plateau (Smith and Foggin, 1999). This species is distributed throughout Trans-Himalayan range above 3000 masl. *O. curzoniae* is reported from Annapurna Conservation Area (ACA) and may be found from Shey-Phoksundo National Park (Abe, 1971; Mitchell and Punzo, 1975; Suwal et al., 1995; Shrestha, 2003) of Nepal.

***Ochotona macrotis* (Günther, 1875):** *Ochotona macrotis* is reported from Sagarmatha National Park, Langtang National Park, Makalu Barun National Park and Rara National Park in Nepal (Kawamichi, 1968; Abe, 1971; Kawamichi, 1971b; Suwal et al., 1995; Shrestha, 2003; Koju et al., 2011; 2012c; Koju and Chalise, 2013). The Large-eared pika occupies elevations between 2,500 m and 6,400 m (Thomas and Hinton, 1922). It occupies higher elevations when sympatric with *O. roylei* (Smith et al., 1990). There are currently five recognized subspecies in the world: *O. macrotis auritus, O. m. chinensis, O. m. macrotis, O. m. sacana*, and *O. m. wollastoni* (Hoffmann and Smith, 2005). One molecular study concluded that *O. macrotis* is a sister species of *O. roylei* (Yu et al., 2000;) but Lissovsky (2014) concluded them as separate species from molecular and morphological study.

The general body colour of this species at dorsal side is pale brownish gray with anchored tinge. Along the sides of the face, across the shoulders and from the nose over the occipital, the general grayish colour is tinged with rufous, which is more marked during summer. In winter, the dorsal colour changes to a dense fluffy pale gray with a tinge of straw yellow. The four legs are all about the same length and the feet, including the soles, are covered with fur. An adult large-eared pika is 15 to 20.4 cm (6 to 8 inches) long (Smith and Xie, 2008; Smith et al., 2010). The ears are broader in average and length of external ear is between 23.1 - 29.0 mm (Kawamichi, 1971b). There are usually two oval foramina above and front of the orbit at the anterior end of the frontal bones. They have longer ear in comparison to *O roylei.* There is thick clad with longer hair inside the ear in *O. macrotis* (Kawamichi, 1971b; Smith et al., 1990; Koju et al., 2011). The dark grayish colouration of *O. macrotis* in winter seems effective for camouflage, protection to sunny grayish slide rocks at least for the observer (Kawamichi, 1971b). The colouration of fur is change according to season in large eared pika of Langtang National Park (Koju et al., 2012c).

The life span of this species of pika is three years of age (Bernstein and Klevezal, 1965). *O. macrotis* usually has two litters per year (Smith et al., 1990). Yearlings of a population are able to breed. The reproductive periodicity of *O. macrotis* is April to mid-August. Gestation is approximately 30 days (Smith et al., 1990).

Ochotona nubrica **(Thomas, 1922):** *Ochotona nubrica* occurs in the trans-Himalayan region from the mountains in south Xizang, China, across the Tibetan plateau. *Ochotona nubrica* inhabits alpine and subalpine desert scrub, where it is assumed to be burrowing, rather than talus dwelling (Smith et al., 1990; Smith and Xie, 2008). The subspecies *O. n. lhasaensis* occurs in alpine steppe (Smith et al., 1990). *O. nubrica* forms well defined family group territories, but little is known about reproductive biology. The body length of this species is 14.0-18.4 cm. This species is characterized as a habitat generalist (Smith and Xie, 2008). *O. nubrica* occurs at elevations between approximately 3,000 to 4,500 m. In Nepal, this species is reported from Annapurna Conservation Area (ACA) and may be found from Shey-Phoksundo National Park (SPNP) and from Mustang and Manang district (personal communication with Dr. Mukesh K Chalise). They inhabit in Tibetan-alpine desert biotope open grass and scrubland dominated by *Caragana* species and *Juniperus* species. Sometimes they are seen rushing from scrubs to scrubs and among rocks, boulders, talus and base of cliffs (Abe, 1971; Mitchell and Punzo, 1975; Suwal et al., 1995; Shrestha, 2003).

***Ochotona roylei* (Ogilby, 1839):** *Ochotona roylei* is a primarily crepuscular in habit (Smith *et al*., 1990). There are two recognized subspecies: *Ochotona roylei nepalensis* and *O. r. roylei* (Hoffmann and Smith, 2005). *O. roylei* is reported from Langtang National Park, Rara National Park and Sagarmatha National Parks between elevations of 2,500 masl and 5,000 masl in Nepal (Kawamichi, 1968; Abe, 1971; Shrestha, 2003; Khanal, 2007; Koju et al., 2011). It is reported from Api Nampa CA (Koju and Chalise, 2013), Kalikot, Ramarosan Achham and Bajura too (Khanal et al., 1999). They are smaller in size than *O. macrotis* and have similar winter fur except for the facial parts in which new rufous summer fur is coming up (Kawamichi, 1968). Adult males have a wide chestnut colour band on the throat. They molt the summer fur (Hoffmann and Smith, 2005). During summer the head, shoulders and fore part of the body are bright chestnut coloured, becoming darker on the throat. The remainder of the dorsal surface is dark grayish rufous. Ventrally, the colouration ranges from white to grayish-white to dark gray (Smith et al., 1990). The winter coat is similar, but may show only traces of rufous colouration (Kawamichi, 1968).

The total body length of this species is 15.5-20.4 cm (Smith and Xie, 2008). The length of pinna is smaller than *O. macrotis* that range 21.3 ~ 24.4 mm (Kawamichi, 1971b). The fecundity rate is low. Litter size is on an averages three (Abe, 1971; Mitchell and Punzo, 1975). The breeding season may extend from late spring until late summer and one or two litters may be produced during this time. Royle’s pikas have two pairs of mammae (Mitchell and Punzo, 1975). Newborn pikas are helpless and naked (Nowak, 1999).

***Ochotona thibetana* (Milne-Edwards, 1871):** *Ochotona thibetana* occurs in the mountains of the eastern Tibetan Plateau and along the Himalayan massif in China. *O. thibetana* usually occurs between 2,400 and 4,100 m in elevation (Smith et al., 1990). It is a social, burrowing habit pika that occurs in bamboo and rhododendron forest in the low elevations of its range and in subalpine forest in the high elevations (Smith et al., 1990; Smith and Xie, 2008). They are also reported from rocky areas under such forest canopies (Smith et al., 2010). *O. thibetana* is a generalist herbivore too that creates hay piles of vegetation to use in winter. The reproductive season for *O. thibetana* extends from at least April to July, and generally has a litter size of 1-5. The total body length of this species is between 14.0 cm and 18.0 cm (Smith and Xie, 2008). In Nepal, this species reported from high mountains near Tibetan border in eastern Nepal.

Pika is food for different predators in Himalayan ecosystem. They are a source of food for most predators including weasels (*Mustela* spp.), steppe polecats (*Mustela eversmanii*), Pallas' cat (*Felis manul*), snow leopard (*Uncia uncia*), foxes (*Vulpes* spp.), wolf (*Canis lupus*), brown bear (*Ursus arctos*), Saker falcon (*Falco cherrug*), upland buzzard (*Buteo hemilasius*), black-eared kite (*Milvus lineatus*), golden eagle (*Aquila chrysaetos*), goshawk (*Accipiter gentilis*), and little owl (*Athene noctua*). During winter, snow leopards ate more than 25% of total food from Royle's pika (Oli et al., 1993). Pika increase plant species richness due to disturbance and dispersal, and increase ecosystem functional properties (nutrient cycling, prevention of extensive erosion during the heavy monsoonal rains of summer) (Smith and Foggin, 1999).

Other faunal component mainly small mammals and birds in its habitat interestingly share pika's burrows. Their burrows offer breeding habitat for birds like Hume's Ground jay (*Psudopodoces humilis*), Scaly breasted wren babbler (*Pnoepyge albiventer*), snow finch (*Pyrgiauda davidiana*), and other animals such as lizard (*Phrynocephalus* species) and squirrels (*Spermoptilas* species) (Khanal, 2007). Thus, pika is keystone species for conservation of biodiversity of Himalayan region. It provides shelter to birds, lizards and insects and also helps to increase in plant diversity by distributing in microhabitat condition around the vicinity of the hay piles areas (Primack, 1998).

Climate change is one of the most significant contemporary threats to biodiversity worldwide and is expected to have a profound effect on both individuals and population in animal communities (Isaac, 2009). Climate change and its effect on the species might one of the more difficult challenge faced by natural resource manager. It is given that global temperature could rise as much as 6.4°C by the end of the twenty first century (IPCC, 2007). Pika has thin abdominal skin, high metabolic rate, poor heat dissipation, high body temperature enable them ecologically adapt to cold and high altitude environment (Primack, 1998). Pikas are specific to microhabitat and microclimate on higher peaks with average body temperature of 40.1°C (MacArthur and Wang, 1973). Pikas live in regions with short summers of less than 20 days per year above 25°C (82% of 50 patches), long winters with greater than 180 days per year below 0°C (94%), a freeze-free period of less than 90 days (86%), and annual precipitation of more than 300 mm (Hafner, 1993).

Pika has weak heat tolerance due to lack of autonomic heat loss response, such as thermal panting (no heat loss during respiration) and difficulty of induction of heat tolerant substance, the so called Heat Shock Protein (Yang, 1990). Pikas are extremely temperature sensitive along with thin skin with short hair and are non-hibernating species. So, pika is vulnerable to global climate change (Rodhouse et al., 2010). Their body temperature is generally 2-3°C higher than other small mammals inhabiting in the same rock slides due to high basal metabolic rate and less thermal conductance (MacArthur and Wang, 1973). Pikas cannot easily move to higher altitudes (or to northward), as their habitat is usually fragmented and restricted to small areas (Deo et al., 2008). They may suffer from hyperthermia or death after brief exposure to ambient temperature above 25°C (Smith, 1974). Wolf et al. (2007) reported that pika in California are under extinction due to global warming. He explained the great change in population status, abundance, predation, disease, and interaction with other fauna as impact of climate change. (MacArthur and Wang, 1973; Smith, 1974) had experimentally demonstrated pikas' vulnerability to heat stress. This vulnerability stems from the species' high body temperature (mean 40.1°C), which is higher than that of any other lagomorphs and very near to the species' upper lethal temperature (mean 43.1°C). This high means body temperature reflect a high basal metabolic rate i.e. 143% of that predicted by algometric models.

In Langtang Nepal, locally pika is known as 'Bhragomjin' and respected as Buddhist monk (Koju et al., 2011). People believed that pika is responsible for changing weather. It controls and regulates rain, snowfall, and wind in Himalaya. People there do not kill and disturb pika. They let pika to enter their home and allow them to take food such as potato, cabbage and wheat flour (Koju et al., 2012b). Smith (2004) had reported that soft feces of pika have been used as a folk medicine in central Asia. Api Nampa is in far west of Nepal; local people call 'Hundra' or 'Khar Musa' for pika and use it as traditional medicine. People believe that a piece of pika meat is sufficient for curing diarrhea, asthma, joint pain and keep warm in hoarse cold (Koju and Chalise, 2013).

Although the economic value of pika is minimal, their furs have been used to make felt hat (Smith, 2004). Pikas are generally too small to be a significant food source, but in Russia, as many as 14,000 skins a year were used for high-quality felt until the 1950 (Smith et al., 1990). Pikas have been important, to some extent, for their fur. In the Soviet Union prior to World War II, pikas' fur was used to produce high quality felt. Now the collection of pika skins for this purpose has ceased because of the nominal return to trappers (Smith et al., 1990). In Yakutia, Japan the trapping of northern pika *Ochotona hyperborea yesoensis* for food continued until 1953 (Tavrovski et al., 1971). In Kazakh SSR (former USSR), pikas were trapped until the 1950s. This hunting has no noticeable influence on the pika populations (Sludski et al., 1982).

Smith et al., (1990) reported that pikas are a minor pest of the young green wheat, fodder and vegetable crops grown near their native habitat, and they damage orchard trees (including walnuts and cherries) seriously in winter when green plants are not available. Afghan pikas sometimes completely remove the bark from trees at 25 to 40cm above the ground. The damage varies with the severity of the winter from as little as 0.15% to as much as 5.1% of trees killed and 1.5% to 47.1% damaged per year of hundreds which is worth of thousands US dollar. Chemicals to kill pikas are applied in early spring (before the meadows turn green) or in early winter (after the meadows have dried up) in Qinghai and Tibet in 1958 to 1965 considering pika as pest in agriculture. Pika feed on poisonous plants that help livestock from accidental death (Koju and Chalise, 2013). Similar case was also reported by Chonglu (1982) and Chonglu et al. (1983) in their research of *Ochotona dauurica* from the Inner-Mongolia, China.

1.1.4 Pikas that found in Langtang National Park, Nepal

Among five species of pika in Nepal, only large eared pika (*Ochotona macrotis*) and Royle's pika (*Ochotona roylei*) are found in Langtang National Park. They both have broadly similar structure and habitat (Kawamichi, 1968; Suwal et al., 1995; Yu et al., 2000; Shrestha, 2003; Koju et al., 2011; Lissovsky, 2014). *O. macrotis* and *O. roylei* looks superficially similar (Fig 1).

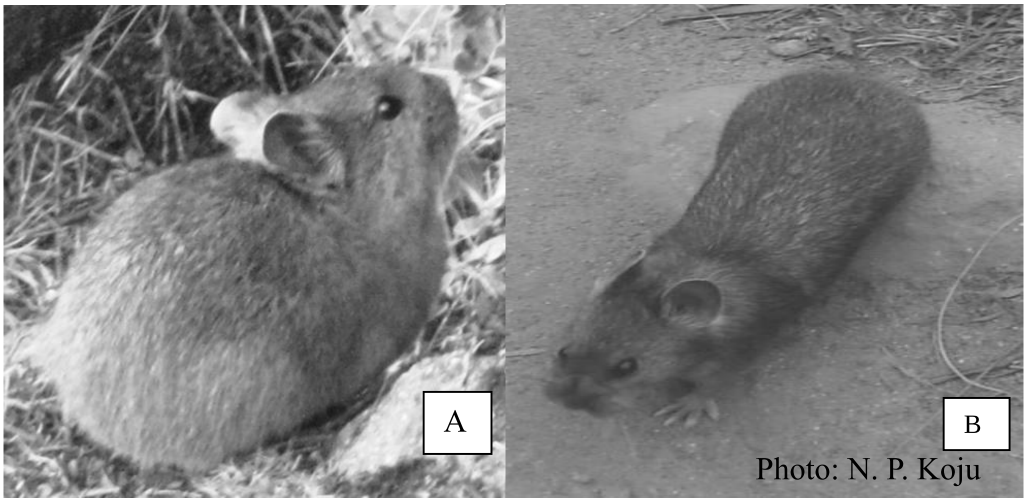


Figure 1: A. *Ochotona macrotis* and B. *Ochotona roylei* in LNP.

Taxonomy of *Ochotona macrotis*

Conservation Status:

World-wide: LC (IUCN, 2010)

South Asia: LC (Molur et al., 2005)

National: LC (Molur et al., 2005)

Taxonomy:

Kingdom: Animalia

Phylum: Chordata

Class: Mammalia

Order: Lagomorpha

Family: Ochotonidae

Genus: *Ochotona*

Species: *O. macrotis*

Binomial Name: *Ochotona macrotis* (Günther, 1875)

Taxonomy of *Ochotona roylei*

Conservation Status:

World-wide: LC (IUCN, 2010)

South Asia: LC (Molur et al., 2005)

National: LC (Molur et al., 2005)

Taxonomy:

Kingdom: Animalia

Phylum: Chordata

Class: Mammalia

Order: Lagomorpha

Family: Ochotonidae

Genus: *Ochotona*

Species: *O. roylei*

Binomial Name: *Ochotona roylei* (Ogilby, 1839)

The both species can be differentiated by the following specific characteristics:

- The coat of *Ochotona macrotis* is paler than *Ochotona roylei*. The colour of the head and the front of *Ochotona macrotis* are tinged with a pale russet colour rather than the brilliant rufous brown colour such as of *Ochotona roylei*.
- *O. macrotis* is larger; has larger and broader ears with dense and long hairs.
- *O. macrotis* has well developed and symmetrical frontal foramina.
- *O. macrotis* has larger and wider tympanic bullae and a more highly arched skull.
- During the winter season, in their area of sympatric, *O. macrotis* is diurnally active whereas *O. roylei* is usually crepuscular (Chapman and Flux, 1990).

1.2 Rational of study

In Nepal, the pika research starts along with mammalian survey in Tibetan side of Everest region (Thomas and Hinton, 1922). They reported two species of pika in Nepal side. Similarly, Biswas and Khajuria (1954) recorded some information of pika in Nepal during their field visit. They described a new Pika *Ochotona angdawi* from Khumbu region from Eastern Nepal. Ellerman and Morrison-Scott (1966) listed two species of Pikas namely *O. macrotis* and *O. roylei* from Nepal in a list of *Ochotona* occurring from Asia. Kawamichi (1968) studied the winter behaviour of pika in Langtang region of central Nepal. He continued with study on daily activities and social pattern of *O. macrotis* and *O. roylei* at Mt. Everest region of Eastern Nepal (Kawamichi, 1971b). Mitchell and Punzo (1975) recorded four new species of pika from other parts of the Himalaya. They collected different species of pikas from different parts of Nepal in between July 1966 to July 1970. Abe (1971) reported three species of pika in Langtang National Park during survey of small mammals in central region of Nepal. Abe further plotted distribution of *O. lama* and *O. dauurica* from alpine deserts of Mustang district with variation in an elevation. Khanal (2007) has reported the symbiotic relation between pika and birds from Rasuwa of Nepal. There is no detail research on ecology of pika in Nepal Himalaya. The seasonal behaviours of different pikas species and their response towards changing climate in Nepal were not explored. There is no study on feeding behaviour of pikas in Nepal. Nepal is agricultural country, alpine talus area are well known for herding goats and sheep but the nutritional value of these high altitudinal forage plants are still not studied. Hence, Nepal Himalaya has a significant gap in pika research, while literatures available until to date are a few based on reviews and short observation. This research will explore ecology of pika along altitude gradient and find out the nutritional values of forage plants at high Himalaya. Climate change is attracting attention of world researchers and people, this research will explore the relation and impact of climate change in pika along the high Himalaya of Nepal.

1.3. Study Area

Langtang National Park (LNP) is located in the central Himalayas of Nepal between 85°15' E to 86°0'E and 28°20'N to 28°32'N. The Park headquarter is of 132.2 km in road distance from Kathmandu, the capital city of Nepal. The park covers 1,710 sq. km area. The shortest highway that connects India and China through Nepal, Pasang Lhamu Highway passes through this National Park. Langtang Lirung (7,245 m) is highest point in the park. Langtang National Park was officially established in March 1976. Its land area includes three districts of Nepal, Rasuwa, Nuwakot, and Sindhupalchowk.

The park experiences distinct summer and winter seasons. From mid-April to mid-June, it is warm but often cloudy with occasional showers. Summer monsoon lasts until the end of September (DNPWC, 2013). The complex topography and composition of geology reflect the wide spectrum of vegetation type, which ranges from 1000 m elevation to alpine region. It has small area of subtropical forest with predominantly Sal species (*Shorea robusta*) just below 1000 meter. Above tree line, alpine shrubs and grasses give way to rock and snow. The Langtang National Park experience distinct summer and winter seasons. The climate varies with altitude. Average daily temperature decreases after the onset of December and continue to February. From mid-April to mid-June, it is warm but often cloudy with occasional showers. The seasonal climate is dominated by monsoon that starts from June and end up around September (Fig 2).

Annual rainfall ranges from 804 mm to 3336 mm in different gradients of national park. The snowline in LNP lies at 5000 masl while tree line is around 4500masl(Kawamichi, 1968). The topography is relatively smooth, especially where a glacier lake culminates;

otherwise, most of the areas have canyons, steep cliff and hanging valleys. Local people inhabit inside the Park according to the Himalayan Parks regulation.

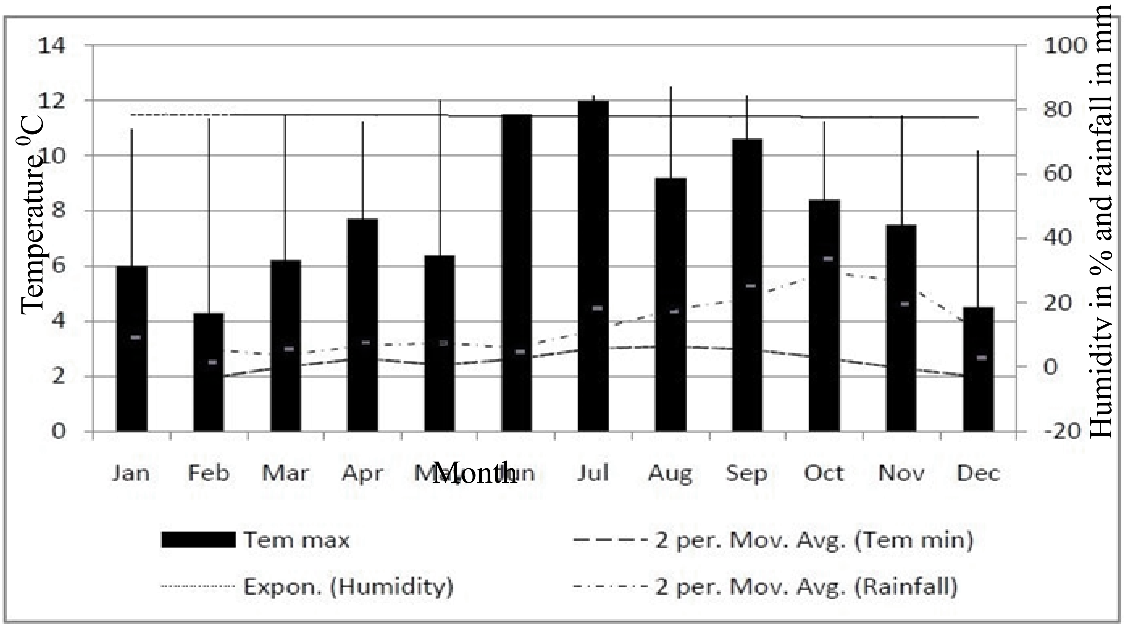


Figure 2: The climate pattern of Langtang National Park at Kyanging, Rasuwa. Source: DHM, 2012

The forest types in LNP above higher elevation categorized to alpine tundra vegetation. Larix (*Larix himalaica*), Oak (*Quercus semecarpifolia*), Chirpine (*Pinus roxburghii*), Maple (*Acer* spp.), Fir (*Abies spectabilis*), Blue Pine (*Pinus wallichiana*), Hemlock (*Tsuga dumosa*), Spruce, many colourful flowering species like *Gentiana*, *Primula*, *Saxifraga* and various species of Rhododendron constitute the floral elements.

The Langtang National Park harbours 46 mammalian species, the significant faunal components such as Snow Leopard (*Uncia uncia*), Red Panda (*Ailurus fulgens*), Musk Deer (*Moschus chrysogaster*), Himalayan Thar *(Hemitragus jemlahicus)*, many species of birds and butterfly species (Chalise, 2010). A huge area of the park is covered with pastures, rocks, bare ground and snow/ glaciers. Langtang National Park consists of the Gosainkunda Lake, the lake listed in Ramsar site and holy lake for both Hindu and Buddhist pilgrim. Annually Thousands of pilgrim visit the lake in April and August (Koju et al., 2013). Langtang Region is one of the best examples for the bio-diversity of plants and animals. The variation in altitude and topography along with the existing forest cover provides habitat for wide range of animals. The Clouded leopard (*Pardofelis nebulosa*), Snow leopard (*Uncia uncia*), Wild Dog (*Cuon alpinus*), Wolf (*Canis lupus*), Red Panda (*Ailurus fulgens*), Musk deer (*Moschus chrysogaster*) are rare species found in the National Park. These all are protected and endangered species in Nepal while Snow Leopard, Musk Deer and Red Panda are on the world list of endangered species (Chalise, 2003).

The research was concentrated in Ghodatabela, Langtang village and around to Kyanging that were visited in Langtang valley route. Similarly Bhanjyang (near Chandanbari), to Suryakunda, then to Magingoth were visited in Gosainkunda route (Fig 3).

This field study was conducted from April 2011 to January 2014. Six field visits were carried in covering all season in area of 26 square 5 kilometer (Approximately 53 km length and 200 meter width). The thesis a conceptual framework was designed (Page 16)

1.4. Objectives

The main objective of the research is to study the ecology of pika as an indicator species of Nepal Himalaya. However, following specific objectives will be dealt in detail.

a. To study the population distribution, density and behaviour pattern of pika (*Ochotona* species.) in Langtang National Park, Nepal.

b. To study habitat preference of different species in different altitudinal gradients.

c. To analyze the value of nutrients in plants/forage consumed by pika in different altitudinal gradients.

d. To explore the impact of climate change in ecology of pika during study period.

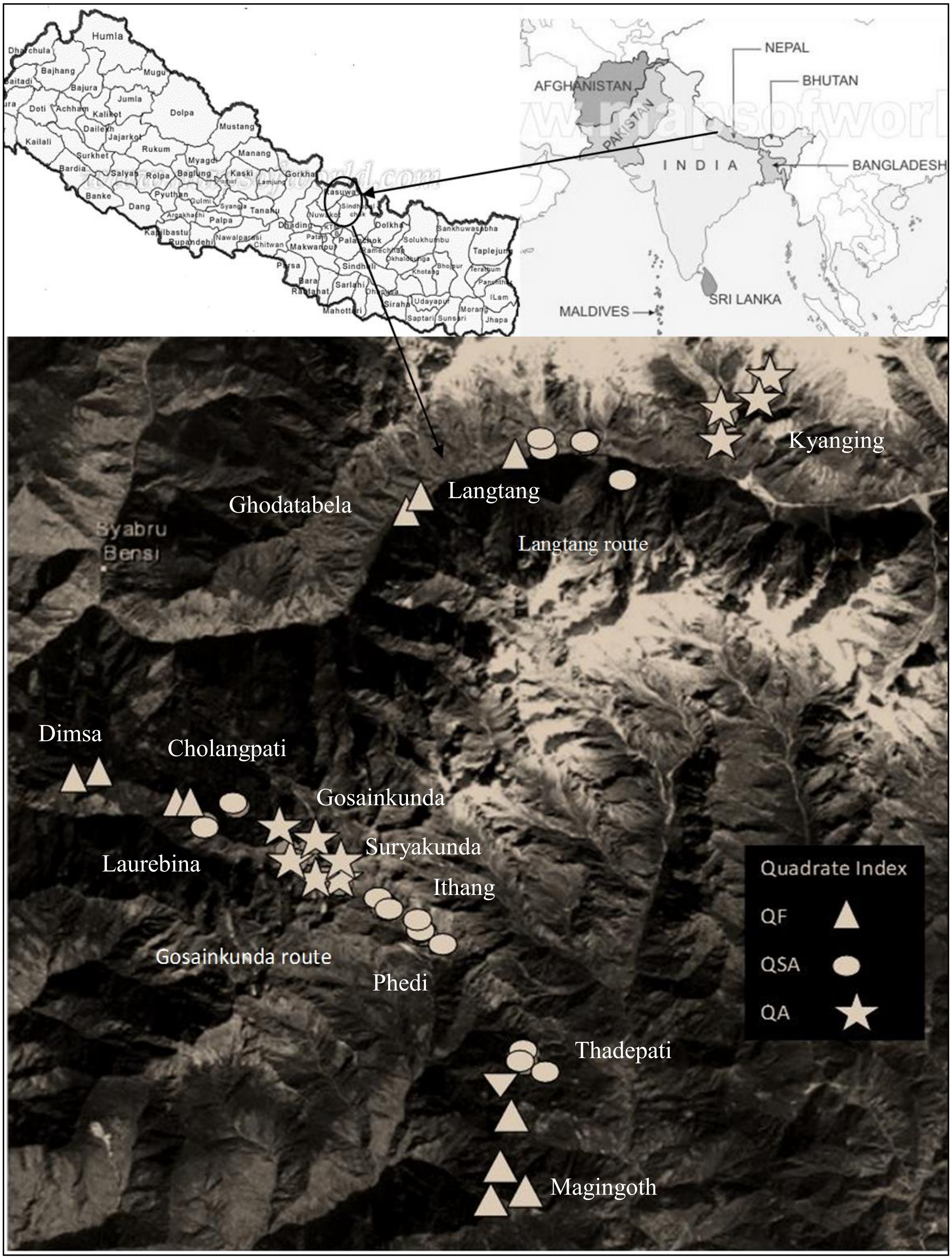
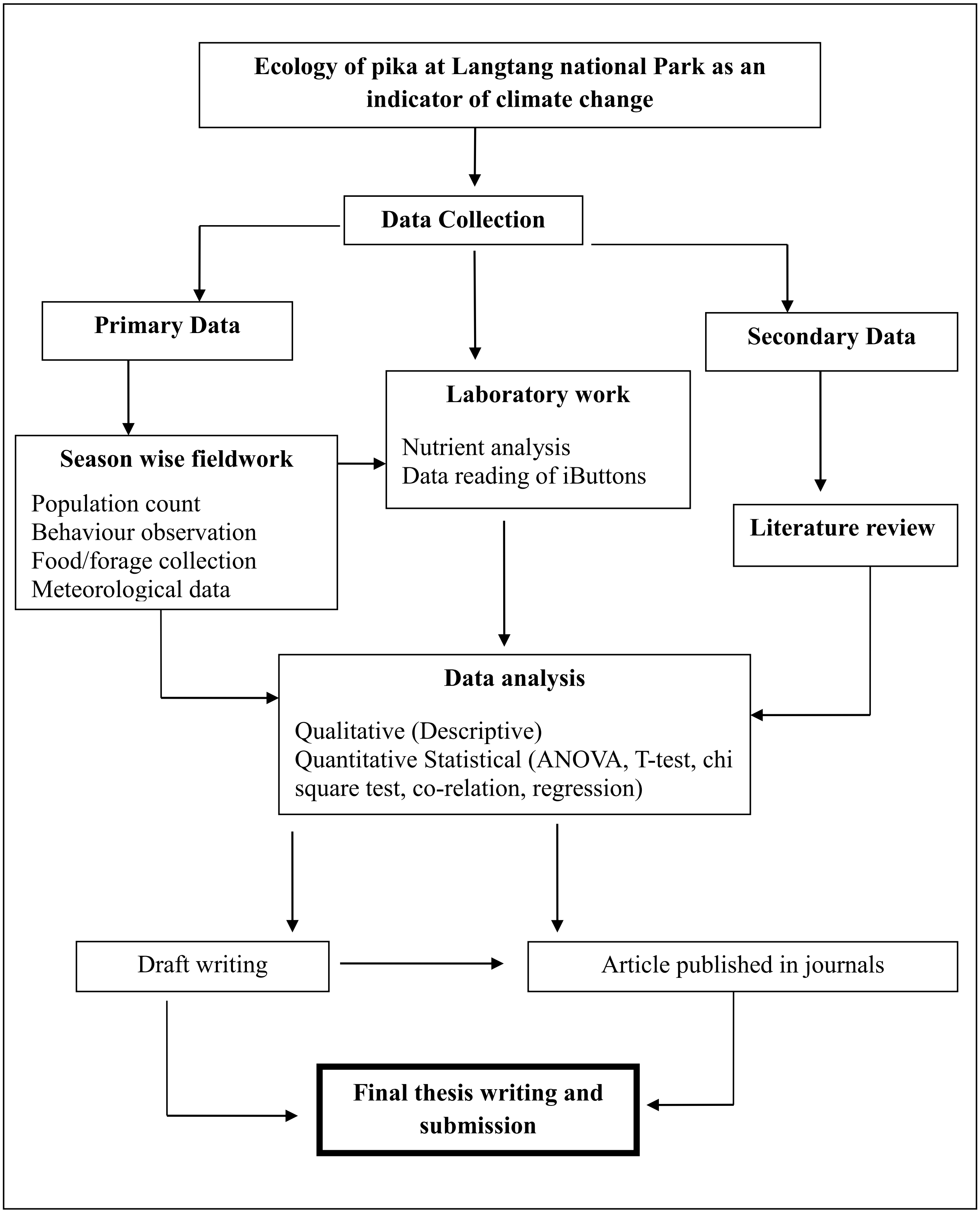


Figure 3: Map of Nepal showing Study area in Langtang National Park.

1.5 Conceptual framework



CHAPTER 2

2. LITERATURE REVIEW

Fossil study of pika

Pikas have lived in North America since the Hemphillian land mammal age (late Pliocene). At least three species, *O. whartoni* (extinct giant pika), *O. princeps* (the living species), and unidentified large and small forms, lived in North America during the Quaternary (Mead, 1987). Mead (1987) recorded forty-six localities of Quaternary-age pikas. Their individual dung pellets provide direct radiocarbon dates and micro histological remains permit dietary reconstructions. Pika lived in northeastern portions of the continent during the Illinoisan glacial age and possibly earlier. During the Wisconsinan glacial period, pika stayed in the mountainous west, but an exception exists. It is proposed that pika were not restricted to rocky/talus slopes during the Pleistocene, as is the living species in North America.

Depending on the time scale considered, pikas are either expanding their range in response to regional cooling (100,000-yr and 1000-yr scale) or retreating in the face of regional warming (10,000-yr and 100-yr scale), which in mesic habitat results in filling of taluses by vegetation encroachment and soil formation (Hafner, 1994).

Mead and Grady (1996) examined 526 fossil specimens (ranging in age from approximately 850,000 to 8670 yr B.P.) from five of different caves of northeastern North America. Their study on radiocarbon ages imply that *Ochotona* lived in eastern North America during the late Pleistocene and into the earliest Holocene.

Morphological and molecular evidence indicates that the Ochotonidae separated from the Leporidae during the Oligocene, approximately 37 Mya. The Ochotonidae originated in Asia, but had spread to North America by the late Oligocene. Throughout their Holarctic range, and even extending into northern Africa, pikas differentiated and became quite diverse during the Miocene. Modern pikas first appeared in Asia during the early Pliocene and spread to North America by the mid-Pliocene. The only two-pika genera to appear in historical times, *Prolagus* and *Ochotona*, appeared in Europe by the late Pliocene. Following the extinction of *Prolagus*, *Ochotona* became the only living representative of the family that had flourished with as many as 25 fossil genera (Smith, 2008).

Ochotonids (pikas) are an ancient group of mammals originating in the Oligocene of Asia and flourishing in the Miocene of the Old World. During the Pliocene, they reduced both their diversity and abundance, Only the Pleistocene genus *Ochotona* survived to the present. Their current geographic diversity is concentrated in Asia, where 28 species exist today. Outside of Asia, ochotonids are represented by one living species in Europe and two living species in North America (Erbajeva et al., 2011).

Structure and physiology of pika

Pikas are unpopular small lagomorphs having rounded ears, short legs and devoid of tails. They have little longer front legs than the rear ones. These animals are absolutely restricted to the Himalayas, the mountains and steppes of central Asia, and the mountains of western North America (Prater, 1965).

Pikas attain a maximum age of 7 years in Alberta and Colorado. Estimated yearly losses of adults did not differ significantly between sexes, years of the study, or among collecting areas, and averaged 46%. Age-specific rates of mortality were greatest in the 0–1 and 5–7 year age groups (Millar and Zwickel, 1972b).

Pikas, unlike rabbits and hares, have several acoustically and functionally distinct vocalizations, the vocal responses of pikas to playback of recorded vocalizations of two dialects in pikas of USA. Pika vocalizations were tape-recorded in twenty-six locations in Wyoming, Colorado, Utah, and New Mexico. Two dialects (based on duration of note and frequency of fundamental) were found in short calls. One dialect was north of the Colorado River (dialect A), and the other was south of the Colorado River (dialect B). There was seasonal variation in the incidence of vocalizations with a peak of songs in late spring and a peak of short calls in late summer (Somers, 1973).

The only distinctive morphological differences between representatives of talus dwelling pika and burrowing pikas groups appears to be that vibrissae are longer in talus dwelling pikas, and claws (used for digging) are more powerful and straight in burrowing pikas (Fedosenko, 1974).

Each breeding season two litters are initiated in pika but only one is successfully weaned. Normally, the first litter is successful and the second litter is lost after parturition. Pika mothers put on fat during the gestation of their first litter and these energy resources are utilized during weaning. Thus, second litters, normally conceived following a post-partum estrus, are born when their mother's fat (energy) reserves have been used up. This typically leads to abandonment of the second litter. However, if a mother has lost her first litter to a predator or has abandoned it for other reasons, second litters appear to be a safety valve. Due to the energetic constraints of weaning, there can be a gradual decrease of litter size due to pre-implantation losses, restoration of embryos, or losses during weaning (Ivins and Smith, 1983).

The morphological characteristics and thermal regulatory functions such as constitutionally short rounded ears, small internal tail, extremely thin abdominal skin, high metabolic rate, poor heat dissipation and high body temperature enable them to ecologically adapt to cold and high altitude environment (Yang, 1990).

Territories of pikas are maintained in both sexes by scent marking and vocalizations in American Pika in Colorado, USA. Pikas are only the lagomorphs in which vocalization appears to be highly developed (Chapman and Flux, 1990).

The mating system in pika is classified as facultative monogamous based on the paired configuration, its persistence in time, the interplay of aggression and social tolerance behaviours. Pikas form mated pairs with adults from adjacent territories. Females may exhibit mate choice when more than one potential mate is available in *Ochotona princeps*, in different parts of USA (Smith and Weston, 1990).

The morphological characteristics and the thermoregulatory function of Afghan pikas such as constitutionally short rounded ear, a small tail, extremely thin abdominal skin, moderate LPS-pyrogenic response, high metabolic rate, poor heat dissipation and high blood temperature as compared albino rabbits, enable them to ecologically adapt to cold and high altitude environment (Yang, 1990).

In Afghan pikas (*Ochotona rufescens*), males were bigger and heavier than non-pregnant females. Mean litter size according to embryo count was 3.6 $\pm$ 1.6 (range: 1 - 7 young/female) and by placental scars 4.48 $\pm$0.30 (range: 2 - 6 young/ female). Mean head body length of primiparous females was less than multiparous females. The higher fecundity rate of pika helps to attain its pest status in apple orchards in Ziarat Valley, Baluchistan, Pakistan (Shafi et al., 1992).

Pikas are uniform in size with body mass ranging generally from 70 to 300 g among species. There is little sexual dimorphism in pikas. Pikas occupy two distinctly different habitats: rock piles and talus versus meadow and steppe, and our understanding of pika biology necessarily begins with a comparative examination of the life history characteristics expressed by rock-dwelling and meadow-dwelling pika species (Hoffmann and Smith, 2005).

Foraging and home range of pika

Fossorial animals in North America increase local primary plant productivity, increase plant species richness, aid in the formation, aeration and mixing of soil, and enhance infiltration of water into the soil. The burrowing pikas contribute positively to ecosystem level dynamics by recycling soil (Ellison, 1946).

Pikas rely on collected hay for warm bedding and food. Pikas gather fresh grasses and lay them in stacks to dry. Once the grasses dry out, the pikas take this hay back to the burrows for storage. It is not uncommon for pikas to steal hay from others; the resulting disputes are usually exploited by neighboring predators like ferrets and large birds (Kawamichi, 1971b).

Various evidences have shown a good relation of livestock to pika’s hay piles. The domestic cows and horses generally locate Pika’s hay piles and start feeding the hays deposited there. This generally happens in winter when the pasture land is covered with snow (Melnikov, 1974). Shrews (*Sorex* species), the insectivorous small mammal generally hunt Pika's hay piles for its diet in alpine region to feed upon insects present there (Naumov, 1974).

Elliott (1980) explained that among 26, three plants species *Smilacina stellata, Apocynun adrosamifoium* and *Fragaria virginiana* composed 88 percent of the total weight of all hay piles of *Ochotona princeps* in Central Idaho, USA

Pikas act as allogenic ecosystem engineers through the formation of hay piles that accelerate soil development and increase fertility in low productivity alpine and subalpine talus and boulder fields, where soils are often shallow, alkaline, and nitrogen impoverished (Mattson, 1980).

There may be competitive relationship between pikas and other grazing herbivores as well. There is inverse relationship between pikas and the density of small rodents near the middle Lena River, Russia with dense population of northern pika (*Ochotona hyperborea*). Nevertheless, during winter at this site voles are often caught on the hay piles of pikas (Safronov and Akhremenko, 1982). They further suggest the sex ratio of pikas in this area is 1:1 in this habitat.

During late summer and early fall (July-September), haying, the gathering of meadow vegetation followed by storing it in their talus territories. It made up almost 55%of the pikas' surface activity. After haying ceased, pikas continued to feed in the meadows until snowpack, cold temperatures, and the absence of surface vegetation made this impossible. Beginning in February, individuals remained under the snowpack feeding on vegetation from their hay piles and on lichens available below the snow. Surface activity was not seen again until May when spring vegetation began to appear (Conner, 1983).

The home ranges of resident adult males and females pikas were of equal size on talus. Members of the opposite sex normally occupied adjacent home ranges, and this spacing apparently results from the balance of agonistic and affiliative behaviours exhibited by nearest-neighbor heterosexual pairs. Most pikas juveniles were philopatric in nature (Smith and Ivins, 1983).

The heavy grazing by pikas in the meadows at the edge of the talus may profoundly alter the composition and diversity of plant communities. Foraging by alpine pikas decreases the percentage of flowering plants, decreases the store of seeds in the soil, and slows down succession of the plant community by eating young trees (Huntly, 1987).

In Colorado, USA single *Ochotona princeps* population had the average hay pile size 28 kg of fresh vegetation which represents 14,000 foraging trips during 8-10 weeks of the summer (Dearing, 1997).

Adult female pikas become intolerant of their young soon after weaning and attempt to exclude them from their territory. Other adults apprehend and chase unfamiliar juveniles from their territories. Thus, the juvenile's survival is directly contingent on its finding a vacant territory to occupy (Smith and Gilpin, 1997).

Peacock and Smith (1997) concluded adult pikas are individually territorial and rarely disperse by using multilocus DNA fingerprinting in Harvey Monroe Hall Natural Area (HMHNA), California, USA. They further suggest an average mortality rate in pika populations of 37-53% each year, and found that very few pikas survived at the study population for the four years of the study.

The burrow system of *Ochotona dauurica* has three entrances and a nest chamber, which connect the three burrows. Multiple nest entrances provide access to refuge for pikas active on the ground surface from aerial and terrestrial predator and multiple burrow provide refuge against intrusion of predator (Kawamichi and Dawanyam, 1997).

Pika is allogenic engineers in alpine talus that build caches of vegetation, which serve as a food source during, winter in alpine and subalpine habitats. Hay piles appear to degrade over time and form patches of nutrient rich soils in barren talus areas. Pikas also help in nutrients recycling and enrich the soil nutrients (Aho et al., 1998).

The pikas are considered the best-known mammalian example of a classic metapopulation with significant population turnover, primarily influenced by habitat characteristics. Forest matrix and other dispersal barriers separate suitable habitat patches; as such, a natural metapopulation structure is established (Moilanen et al., 1998).

Male pikas did not disperse to gain advantages in competition for mates, as evidenced by their moving to families with significantly fewer females. Females, however, moved to families with significantly more males. Males provide abundant paternal care, and significantly, more offspring per female survived to become adults from families. Evidence concerning the influence of inbreeding avoidance on natal dispersal was indirect. Some males exhibited natal philopatry, thus some families had opportunity for close inbreeding. Males and females that dispersed had no opposite-sex relatives in their new families. Philopatric pikas may have benefited by remaining in families that exhibited low local densities and philopatric females might have benefited from social cooperation with relatives (Dobson et al., 1998).

The plateau pika is a keystone species because it: (i) makes burrows that are the primary homes to a wide variety of small birds and lizards; (ii) creates microhabitat disturbance that results in an increase in plant species richness; (iii) serves as the principal prey for nearly all of the plateau's predator species; (iv) contributes positively to ecosystem level dynamics. The plateau pika should be managed in concert with other uses of the land to ensure preservation of China's native biodiversity, as well as long-term sustainable use of the pasture land by domestic livestock (Smith and Foggin, 1999).

The sub generic classification of *Ochotona* species needs to be revised because each of the two subgenera in the present classification contains species from the mountain group. To solve this taxonomic problem so that each taxon is monophyletic, i.e., represents a natural clade, *Ochotona* could be divided into three subgenera, one for the shrub–steppe species, a second for the northern species, and a third for the mountain species. The inferred tree suggests that the differentiation of this genus in the Palearctic Region was closely related to the gradual uplifting of the Tibet (Qinghai-Xizang) Plateau (Yu et al., 2000).

Franken and Hik (2004) suggest influence of habitat quality, patch size and connectivity between patches, patch quality on local extinction and recolonization need to be more fully incorporated into metapopulation models.

The average elevation of now-extinct Great Basin pika populations during the late Wisconsinan (c. 40,000–10,000 radiocarbon years ago) and early Holocene (c. 10,000–

7500 years ago) was 1750 m. During the hot and dry middle Holocene (c. 7500–4500 years ago), the average elevation of these populations rose 435 masl to 2168 masl. All prehistorically known late Holocene (c. 4500– 200 years ago) populations in the Great Basin are from mountain ranges that currently support populations of this animal, but historic period losses have caused the average elevation of pika populations to rise an additional 152 m (Grayson, 2005).

Pikas and livestock can co-exist in inner Mongolia, China because each has exclusive access to a forage resource unavailable to the other group: pikas have the ability to bite down the vegetation deeper than livestock (Retzer and Reudenbach, 2005).

The newly reported pikas of the recent age from the Armenian Highlands of Turkey and Iran slightly differ from those inhabiting the rest of Iran and are reported as *O. rufescens* (Stanislav et al., 2006).

A long call of Japanese pikas (*Ochotona hyperborea yesoensis*) consisted of 3–13 elements, each with a characteristic W-shape wave. There was apparent individual variation in sonographic patterns and the fundamental frequencies. Such individual variation did not differ with animal age, or through the reproductive and non-reproductive seasons (Kojima et al., 2006)

Plateau pikas maintained a relatively constant body mass throughout the year and showed no seasonal changes in body fat mass and circulating levels of serum leptin. However, non-shivering thermogenesis, cytochrome c oxidase activity, and mitochondrial uncoupling protein one (UCP1) contents in brown adipose tissues were significantly enhanced in winter. Further, serum leptin levels were positively correlated with body mass and body fat mass while negatively correlated with UCP1 contents. Together, these data suggest that plateau pikas mainly depend on increasing thermogenic capacities, rather than decreasing body mass, to cope with cold, and leptin may play a potential role in their thermogenesis and body mass regulation (Wang et al., 2006).

Adult pikas in *Ochotona princeps* survival across the entire site was positively correlated to the Pacific Decadal Oscillation (PDO) with a time lag of 1 year, and was uncorrelated to adult density. The PDO was negatively correlated to the timing of spring snowmelt at our site, implicating the importance of earlier spring conditions and plant phenology on the subsequent winter survival of adults and therefore, population growth. When subpopulations were analyzed separately, survivals and fertilities were variously correlated to lag PDO and adult densities, but the patterns varied spatially. Therefore, the mechanisms underlying V(λ) can vary substantially over relatively short distances (Morrison and Hik, 2007) .

Ochotona pallasi in Southern Mongolian steppes positively influences soil nutrient levels on its burrows, which leads to increased grassland productivity even under dry conditions. Thus, *O. pallasi* does not deteriorate site conditions, and the need for presently applied pest control schemes aimed at this species should be reassessed (Wesche et al., 2007).

Plateau pikas (*Ochotona curzoniae*) are considered a pest species on the Tibetan Plateau of China, because they compete with livestock for forage and their burrowing could contribute to soil erosion. The effectiveness of pest control programme in Tibet has not been measured, and it is not known whether changes in livestock management have exacerbated problems with plateau pikas or compromised their control. Current control programmes have limited effect because populations of plateau pikas can recover in one breeding season. There was no apparent increase in forage production in areas where plateau pikas were controlled. However, plateau pikas appear to benefit from changes in grazing management, with low-density populations declining less over winter inside fenced areas than elsewhere (Pech et al., 2007).

Arthur et al., (2008) studied about relationships between the local seasonal abundance of small birds and the density of pika burrows and livestock grazing practices and local poisoning in the Qinghai–Tibet plateau. They suggest poisoning pikas in spring had no detectable effect on the local abundance of birds the following autumn. However, two ground-nesting species, white-rumped and rufous-necked snow finches, showed positive associations with the density of pika burrows, indicating that long-term pika poisoning could reduce the density of these species by reducing the density of pika burrows of pikas.

The adaptive evolution may occur in leptin of pika, which may play important roles in pikas' ecological adaptation to extreme environmental stress. It was speculated that cold, and probably not hypoxia, may be the primary environmental factor for driving adaptive evolution of pika's leptin (Yang et al., 2008).

Pika distribution was found to be highest in mixed habitat, north east aspect and under very high rock cover whereas open habitat, east facing slope and low rock cover show lowest distribution in Kedarnath Wildlife Sanctuary, Uttarakhanda, India (Haleem et al., 2012).

The forage selection criteria in *Ochotona roylei* did not differ between field and laboratory experiments. The parameter estimates of best fit models indicate that the influence of leaf size or amount of avoided substance on pika forage selection was modulated by the magnitude of predation risk (Bhattacharyya et al., 2013).

Climate change

Populations of American pikas (*Ochotona princeps*) continue to suffer extirpations, and although the lower bounds of the pika's elevational distribution are shifting upslope across the Great Basin, the new discovery of a low-elevation population of pikas in a mountain range was done from which they had not been reported previously. Although thermal influences appear to be the single strongest determinant of pika distribution currently, such influences interact with a number of other factors to determine persistence (Beever et al., 2008).

Pikas are native Himalayan species, they are very sensitive and highly susceptible to slight change in climatic elements, mainly increase in temperature. This vulnerabilities of biodiversity to climate change have been assessed in this study based on field observations made on a small mammal named Pika or Mouse-hare (*Ochotona* species) and a species of butterfly (*Parnassius* species, Apollo butterfly). Considering the high susceptibility of the two species to rise in atmospheric temperature, they are used as the principal indicators of climate change (Deo et al., 2008).

Galbreath et al. (2009) explored the influence of elevation shifts on genetic differentiation and historical demography in an alpine specialist, the American pika (*Ochotona princeps*).

Pika populations was divided into five genetic lineages that evolved in association with separate mountain systems, rather than lineages that reflect individual sky islands. This suggests a role for glacial-period elevation shifts in promoting gene flow among high-elevation populations and maintaining regional cohesion of genetic lineages.

Pika populations associated with different mountain systems have followed separate but not completely independent evolutionary trajectories through multiple glacial cycles. Range expansion associated with climate cooling (i.e. glaciations) promoted genetic admixture among populations within mountain ranges. It also permitted periodic contact and introgression between phylogroups associated with different mountain systems, the record of which is retained at nDNA but not mtDNA loci (Galbreath et al., 2010).

Climate change was defined as change in our thermal metrics between two 31 years periods: 1945–1975 and 1976–2006. The patterns of persistence were well predicted by metrics of climate. Our best models suggest some effects of climate change; however, recent and long-term metrics of chronic heat stress and acute cold stress, neither previously recognized as sources of stress for pikas, were some of the best predictors of pika persistence (Beever et al., 2010).

Climatic relationships from the PRISM model for the Sierra Nevada (SN), California and southwestern Great Basin sites of USA showed wide tolerance, with average precipitation 910 mm, average minimum temperature 23.9 ^{0}C, and average maximum temperature 8.7 ^{0}C. Unusual features of rock ice feature landforms make them important refugee for pikas as climate warm (Millar and Westfall, 2010).

Pikas were also more likely to occur on lava flow sites with higher structural complexity and forb cover. An area of pahoehoe lava encompassing 250 km^2 in the northern portion of Craters of the Moon contained 91% of pika detections and all predicted site-occurrence probabilities. Craters of the Moon may provide long-term refugia for the species, given the extent of lava habitat there. However, the importance of elevation suggests that accelerated climate change could erode suitable pika habitat in the park (Rodhouse et al., 2010).

Nichols (2011) reported that the changes over time of unknown age pika fecal pellets up to 36 years old. Predictable changes in diameter, internal consistency, and colour of pellets provide a method to approximate the dates of last occupation in patches where pikas have been extirpated.

The rapid, eco-regional range shift of this small, talus dwelling species pika stands in remarkable contrast with the dynamics and determinants of endangerment previously observed for most terrestrial species, and to earlier extinction determinants for *O. princeps* in this region. Further investigation of widely distributed species will clarify rates at which biotic response to environmental change is occurring, and how factors driving that change are evolving in different portions of the earth (Beever et al., 2011).

The high inbreeding and low genetic variation is the best characterized by American pikas of Columbia River Gorge, Oregon. A high degree of structure was detected among sites, and differentiation increased where topographical features potentially served as dispersal barriers. Although pikas inhabiting geographically proximate sites tended to cluster at similar elevations, there was little evidence of statistically significant migration. Indirect measures, however, such as within-site relatedness and inbreeding, strongly suggested a pattern of male-biased dispersal (Robson, 2013).

The examination of 1090 intact skulls, representing all recognized Palearctic species of pika (*Ochotona*), as well as 394 complete sequences of the cytochrome *b* gene from all recognized pika species. The results of the analyses suggest that 28 species should be recognized in the genus (Lissovsky, 2014).

CHAPTER 3

3. MATERIALS AND METHODS

3.1 Methodology

3.1.1 Habitat characterization: Quadrat, transect and block design (Martin and Batson, 1993) method was applied to calculate population distribution and density. The study was carried in the trail transect of 53 Km length and 200m wide in two routes (Ghodatabela, to Lanshisa Kharka in Langtang valley route. Similarly, Dimsa to Gosainkunda, then Suryakunda to Magingoth in Gosainkunda route (See Fig 3). Total fifty quadrats were permanently plotted in pika habitat to study their population abundance and behaviour. In these permanent quadrats, the small sized 20m × 20m quadrat, 5m × 5m quadrat and 1m × 1m quadrat was plotted randomly with in the permanent quadrats used to calculate population density and behaviour. The important index (IVI) value of the plants was calculated by formula IVI= ∑ (RF+RD+RA). Here RF= relative frequency, RD= relative density and RA= relative abundance

All these locations along altitudinal gradients were categorized into three habitats:

1. **Habitat of pika inside the forest and its edge area**: It belongs to area from Magingoth 3000 m to below Thadepati (below 3500 m) at south, Dimsa (3000 m) to Cholangpati (below 3500 m) at west in Gosainkunda route and from Ghodatabela (2900 m) to Langtang at northwest in Langtang route of LNP (Table 1).
2. **Habitat of pika in subalpine and broken rocks area**: This habitat represents the area above tree line with some shrubs and rocks boulder. It belongs area above Thadepati (3500 m) to above Phedi (4000 m) and above Cholangpati to Laurebina (3910 m) in Gosainkunda route. Similarly, it was areas above Langtang (3400 m) to Thulo Dhunga (3810 m) in Langtang route.
3. **Habitat of pika in alpine and talus area**: This is the habitat without bushes and shrubs. It contains alpine meadow and rocks with boulder. The area above Laurebina to Suryakunda, above Phedi to Suryakunda in Gosainkunda route and Langtang Glacier and Lanshisa around Kyanging were in this habitat.

Table 1: Location and their coordinates of Quadrats for *O. roylei*.

Quadrat	Location		GPS Coordinate		Slope/ Aspect
		Elevation (m)	Latitude	Longitude	
QF1	Magingoth	3332 *	27 °58'18.28"N	85 °29'4.55"E	56 °E
QF2	Magingoth	3237	27 °58'49.68"N	85 °29'6.20"E	54 °NE
QF3	Magingoth	3481	27 °59'51.37"N	85 °29'24.78"E	54 °NW
QF4	Chandanbari	3301	28 °6'35.98"N	85 °20'29.17"E	37 °S
QF5	Cholangpati	3611	28 °6'0.51"N	85 °22'18.23"E	46 °SW
QF6	Cholangpati	3621	28 °5'58.57"N	85 °22'16.60"E	19 °N
QF7	Polangpati	3571	28 °6'3.66"N	85 °22'30.97"E	36 °W
QF8	Dimsa	3063**	28 °6'30.71"N	85 °19'57.66"E	29 °SE
QF9	Ghodatabela	3018***	28 °11'47.60"N	85 °27'10.51"E	54 °SW
QF10	Ghodatabela	3037	28 °12'0.95"N	85 °27'33.53"E	61 °W
QSA1	Thadepati	3633	28 °0'46.46"N	85 °29'30.32"E	59 °N
QSA2	Thadepati	3638	28 °0'50.81"N	85 °29'36.74"E	59 °NW
QSA3	Thadepati	3597	28 °1'3.10"N	85 °29'35.63"E	70 °W
QSA4	Laurebina	3910	28 °5'34.89"N	85 °22'47.59"E	30 °W
QSA5	Laurebina	3853	28 °5'56.96"N	85 °23'30.02"E	31 °W
QSA6	Langtang	3324	28 °12'46.46"N	85 °29'28.62"E	47 °S
QSA7	Langtang	3379	28 °12'57.71"N	85 °30'4.46"E	58 °W
QSA8	Phedi	3720	28 °3'15.49"N	85 °27'53.75"E	60 °SE
QSA9	Phedi	3760	28 °3'28.05"N	85 °27'32.09"E	60 °S
QSA10	Phedi	3872	28 °3'34.14"N	85 °27'27.35"E	60 °S
QA1	Ithang	4227	28 °3'56.90"N	85 °26'43.10"E	53 °SW
QA2	Ithang	4233	28 °3'57.54"N	85 °26'42.40"E	62 °SW
QA3	Ithang	4256	28 °3'59.83"N	85 °26'40.26"E	54 °W
QA4	Suryakunda	4657	28 °4'25.16"N	85 °25'43.92"E	42 °SW
QA5	Gosainkunda	4452	28 °5'2.03"N	85 °25'0.27"E	60 °SW
QA6	Gosainkunda	4451	28 °5'3.53"N	85 °24'36.59"E	47 °S
QA7	Gosainkunda	4647	28 °4'31.53"N	85 °25'26.83"E	65 °NE
QA8	Gosainkunda	4426	28 °4'52.38"N	85 °24'46.08"E	53 °N
QA9	Kyanging	3916	28 °12'58.17"N	85 °33'56.70"E	26 °W
QA10	Near Glacier	4466	28 °14'4.19"N	85 °34'43.75"E	54 °NE

Note: * Lowest elevation of pika observed at south of Langtang National Park
** Lowest elevation of pika observed at west of Langtang National Park
*** Lowest elevation of pika observed at north of Langtang National Park

In those three major selected habitats, total fifty randomly plotted permanent quadrats (thirty each for *Ochotona roylei* and twenty for *Ochotona macrotis* observed areas) were studied for six field works. In the quadrat of 50m×50m, observers were standing with binocular at vantage point to record population encounter and behaviour observation. The coordinate, elevation, slope and aspect of quadrat are recorded (Table 1and Table 2).

Table 2: Location and their coordinates of Quadrats for *O. macrotis.*

Quadrat	Location	Elevation (m)	GPS Coordinate North	East	Slope/ Aspect
QSAM1	Thadepati	3639	28 °1'7.89"N	85 °29'33.76"E	59 °N
QSAM2	Thadepati	3653	28 °0'57.01"N	85 °29'41.64"E	59 °NW
QSAM3	Thadepati	3597	28 °1'03.10"N	85 °29'35.63"E	70 °W
QSAM4	Laurebina	3910	28 °5'34.89"N	85 °22'47.59"E	30 °W
QSAM5	Laurebina	3853	28 °5'56.96"N	85 °23'30.02"E	31 °W
QSAM6	Langtang	3561	28 °12'59.68"N	85 °31'02.55"E	63 °S
QSAM7	Langtang	3391	28 °12'59.65"N	85 °30'04.19"E	63 °SW
QSAM8	Phedi	3732	28 °3'27.21"N	85 °27'28.22"E	60 °SE
QSAM9	Phedi	3760	28 °3'28.05"N	85 °27'32.09"E	60 °S
QSAM10	Phedi	3891	28 °3'31.88"N	85 °27'28.60"E	60 °S
QAM1	Ithang	4219	28 °3'56.73"N	85 °26'45.44"E	57 °SW
QAM2	Ithang	4244	28 °3'57.45"N	85 °26'40.94"E	64 °SW
QAM3	Ithang	4256	28 °3'59.99"N	85 °26'40.19"E	55 °W
QAM4	Suryakunda	4657	28 °4'25.16"N	85 °25'43.92"E	42 °SW
QAM5	Gosainkunda	4452	28 °5'2.03"N	85 °25'00.27"E	60 °SW
QAM6	Gosainkunda	4451	28 °5'3.53"N	85 °24'36.59"E	47 °S
QAM7	Gosainkunda	4647	28 °4'31.53"N	85 °25'26.83"E	65 °NE
QAM8	Gosainkunda	4426	28 °4'52.38"N	85 °24'46.08"E	53 °N
QAM9	Kyanging	4054	28 °13'31.71"N	85 °34'02.09"E	55 °N
QAM10	Near Glacier	4610	28 °14'14.54"N	85 °34'52.87"E	52 °S

Note: QSAM= Quadrat in subalpine area and QAM= Quadrat in alpine and talus area for *Ochotona macrotis*.

To study the feeding behaviour of pika the alpine habitat was again divided into alpine land area and lake premises as area around Gosainkunda Lake). Gosainkunda premises had different ground vegetation from other places and pika consumed all ground vegetation of this area. Every year thousands of pilgrims visit this place. Pikas in this area were observed transferring plastics and were suffering from anthropogenic pollution in 2011. Pikas in this area were not observed from 2012 March too.

3.1.2 Sampling: Scan sampling (Altmann, 1974) continues as practiced by Chalise (2003) in mountain terrain was applied to record the behaviour of pika. Behaviours of pikas were observed seasonally. Study period is divided into two first as summer and rainy season (April-September). In this time, Langtang receive highest temperature and monsoon. The second as cold season (October-March), in this period Langtang receive less rain or no rain and it is cold and dry.

Observations were scattered during the months April, July and October in 2011, January, March and July in 2012 and April, July 2013. Total 127 days fieldwork was conducted trying to collect behaviour data and population abundance in all seasons and different months. Grooming, musing, calling, feeding, foraging, chasing, inside burrow and galloping behaviours were observed as general behaviour by Focal Scan Sampling in interval of one minute. Some special behaviour like mating, drinking of water, defection of pellets, parental care was recorded during observation. Two camera traps were fixed in different places alternatively for 22 nights to record nocturnal behaviour. During observation if pika enter the burrow and did not returned to open field until five minutes its behaviour observation was stopped. For this research, different behaviours were defined as follows:

a) Calling: Making sound is calling. Pika makes two types of sound; long call sound Chirrr…rrr and short call heard as 'chi chi…..'
b) Chasing: Chasing means following others and former try to escape from following ones. Sometime it seems as fighting each other (pseudo fighting) Chasing may be just playing in infants and possible behaviour before mating or territorial defense in adult.
c) Feeding: Eating grass, flower or other parts of plant sitting in one place and collecting them to make hay pile (food storage) is termed feeding.
d) Foraging: The movement for searching, selecting food to eat and feeding food during this movement is termed as foraging.
e) Galloping: Jumping of pika from one rock to other rock or in the ground for few feet distance is galloping.
f) Grooming: Grooming is the process of cleaning body and fur. Pikas use their hind limb most frequently and fore limb and mouth sometime for grooming.

g) Inside burrow: Pika enters burrow and use number of burrows for short time while foraging and feeding. It may be defense behaviour against predator of pikas. The time interval spent into burrow was recorded as inside burrow.

h) Musing: Motionless or just resting on the big stone for short or long time is musing. This behaviour is very common among pika in good sunlight.

To record population abundance, population density and behaviour of pikas fifty 50m×50m quadrats were plotted in trail transect. The population of pika (direct observation) was observed thoroughly and recorded the number that observed within the permanent quadrats. Pika was observed from 5:30 AM to 7:30 PM in summer and 6:30 AM to 5:30 PM in winter. To prohibit mixed up of individuals' behaviour and repetition in population count, photographs from different angle of all observed pikas were taken for individual identification in each trips. Simultaneously, special morphological features of individual pika like scratch or tears in ears, warts in body, fur colour pattern of body and organs size were taken in account.

3.1.3 Capturing and trapping of pika: To observe nocturnal behaviour camera traps (Bushshell HD Model No. 119477) were used (Fig 4).

Photo: Prof. Dr. Randall C. Kyes

Figure 4: A. Fixing camera trap in habitat, LNP. B. Pika captured in camera trap in day light, LNP.

Total four camera traps were used to observed pika's behaviour in our absence. Cameras were placed in all permanent quadrats during all season field works in all habitat. Camera traps were also active during day so it was able to record diurnal behaviours. Camera traps were thermo and motion sensor cameras. They were set to record three pictures at one incident (stimulation) as well video to capture all live activities of pikas at camera range.

Pikas were captured to understand morphology and in situ information using spring traps of 30cm×10cm×10 cm sizes and Sherman traps 30cm×10cm×10cm (Fig. 5).

Figure 5: Using traps to capture live pikas using A. Spring trap and B. Sherman trap, LNP.

Trap was placed in the mouth of active burrow and shelter of pika with some food/bait. Baits contain piece of fresh apple, peanuts butter mixed bread and fresh green grass. Traps were checked frequently in interval of 15 minutes. Traps without pika for more than two hours were reset for different location. Captured pika was handled by using conical net. It was allowed to rest at the angle of the conical net then captured gently by hand at head and body (Fig 6). After live study, they were freed in the same habitat and place.

Figure 6: Methods and items of pika handling after capturing. Photo: Chris Ray

3.1.4 Pika's food collection and nutritional analysis: Raw food plants and parts from three habitats were collected in summer and rainy season to analyze its nutritional value. Six the most consumed forage plants with their respective parts (the most feed/eaten in frequency by pika recorded during observation) were collected in summer and rainy season from respective habitats. 500gm of each plant's part that were recorded during observation of behaviour was collected.

Total 24 plants individual from four different habitats (including Gosainkunda Lake area) during fieldwork at rainy season were collected. Even Gosainkunda lake premises was in alpine and talus area; its forage plants were separately analyzed; as in Gosainkunda premises pika consumed all plants available there and pikas were not observed there after 2012 March.

Collected samples were dried in open air inside the room during field period. They were further dried in hot air oven at 90°C, then grinded and sieved through 1mm sieve size. Macronutrient like phosphorous (P) and potassium (K) were analyzed in Nepal Academy of Science and Technology (NAST) by flame photometry method (Jackson, 1958). This solution was extracted by using Acid Peroxide digestion method. Nutrients like protein; calcium, cellulose (C), hemi-cellulose (HC), Acid Detergent Lignin (ADL), etc. from all collected forage plants were further analyzed in laboratory of Nepal Agriculture Research Council (NARC).

Total Ash Content was determined by ignition at 500°C to 600°C and OM was determined by total ash content minus total nutrient. Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF) and Acid Detergent Lignin ADL were determined by refluxing method. Hemi cellulose (HC) content was determined by drying in an oven at approximately 100°C for 24hrs. Calcium (Ca), Phosphorus (P) and Potassium (K) were determined by spectrophotometric titration.

Moisture content was determined by oven drying. NDF was calculated for total fiber content (Goering and Vansoest, 1970) ADF was measure for total ligno-cellulose and silica content (Vansoest, 1963), and ADL for lignin content (Morais et al., 1991). Phosphorus, was estimated by UV spectrophotometry Cary 100 Bio-UV–vis; Agilent, Santa Clara, CA, USA), and calcium by atomic absorption spectrometry. Potassium contents was estimated by flame photometry (Flame Photometer 128 ° C), and Crude Protein (CP) was measured by the "Anthrone" method (Cary 100Bio-UV–vis).

Rational of different components:

Acid Detergent Fiber (ADF): Acid detergent fiber is the fraction of indigestible plant material in forage, usually cellulose fiber coated with lignin. The ADF value refers to the cell wall portions of the forage that are made up of cellulose and lignin. These values are important because they relate to the ability of an animal to digest the forage. As ADF increases, the ability to digest or the digestibility of the forage will decrease.

Acid Detergent Lignin (ADL): Acid detergent lignin is the percentage of plant material. Lignin reduces digestibility and has been used to predict digestibility. Therefore, higher value of NDF, LDF and ADL reduce the value of digestively of plants. When animal consumed the plants species with higher value of these components, they had to feed more volume for better nutrition.

Cellulose: Cellulose is an important structural component of the primary cell wall of green plants. Hemi cellulose and cellulose indicate the amount of carbohydrate present in plants. These both components are difficult to digest for animal. Higher the value of both hemi-cellulose and cellulose decrease the amount of digestion.

Crude Protein (CP): The approximate amount of protein, which is calculated from the determined nitrogen, contains determined by measuring total nitrogen in a sample and multiplying by 6.25. CP is a mixture of true protein and non-protein nitrogen.

Hemi-cellulose (HC): Hemi-cellulose is the polysaccharide associated with cellulose such as pectin, xylan and pentosane.

Neutral Detergent Fiber (NDF): Neutral Detergent Fiber is the most common measure of fiber used for animal feed analysis. NDF measures most of the structural components in plant cells (lignin, hemi-cellulose and cellulose). The level of NDF in the animal ration influences the intake of dry matter and the time of rumination.

From all the sample Relative Feed Value index was calculated by a formula RFV index= $(120/NDF)\times(88.9-(.779*NDF))/1.29$ (Undersander and Moore, 2002). Similarly, Total Digestive Nutrient (TDN) for grass was calculated by TDN (%)= 105.2-0.667*NDF% and

Net Energy Consumed index was calculated by NEc= 1.12-(.0159%*ADF) (Moore and Undersander, 2002).

3.1.5 Climatic data records: Meteorological data were collected from Department of Hydrology and Meteorology (DHM) that were recorded in meteorological station in Kyanging (3900m), LNP. Meteorological data of maximum temperature, minimum temperature, humidity and rainfall were taken into account from 1983 to 2012 AD. During field research eighteen temperature data logger (DS1921G Thermochron iButtons, Maxim Integrated Products, Sunnyvale, CA, USA) were installed in pika's habitat with difference of 200m elevation gradient in both route of Langtang National Park for recording temperature per day in interval of 90 minutes (Beever et al., 2010; Millar and Westfall, 2010) from 2012 January to 2013 December. 1-Wire Drivers X86 software was used to download data from iButtons. The data of temperature and rainfall was analyzed with regression equation for information on climate change. The current population abundance, distribution and behaviour were compared with earlier information of pika in Langtang National Park to correlate with climate change. Data analysis like correlation, regression, t test and ANOVA was done using R software and SPSS. GIS is used for mapping habitat and population of different pika species.

3.2 Equipment used

Camera, camera traps, GPS, binocular, weighing machine, thermo-hydrometer iButtons (Fig 7), mouse traps, stationery Field gear and logistics, etc. were used to collect various data in field. Laboratory facilities of Nepal Academy of Science and Technology (NAST) and Nepal Agriculture Research Council (NARC) were used to analyze the nutrition value of food plant and parts consumed by pika

Figure 7: iButtons and its accessories**.**

CHAPTER 4

4. RESULTS AND DISCUSSION

4.1 Pikas observed in Langtang in Langtang National Park

4.1.1 *Ochotona roylei*

Ochotona roylei (Royle's Pika) were observed above the elevation of 3005m in Gosainkunda route at Dimsa. They were observed in all three habitats: forest and its edge area, subalpine area and alpine talus area. In Thadepati, Laurebina and Langtang, pika use to enter to local peoples' home, hotels, lodges as well as cowshed frequently. In these places, due to such behaviour, Royle's pikas were more habituated to human presence. They often encounter on human made wall, some of them were also recorded carrying vegetables from farmland of people. The *O. roylei* inhabits in forest were dark coloured than other habitats. The head shoulders and fore part of the body are bright chestnut coloured. The remaining of the dorsal surface is dark grayish rufous. Ventrally, the colouration of pika ranges from white to grayish-white to dark gray. In winter body fur colouration do not vary but little darker than summer. Total five individuals of *O. roylei* were captured for detail information of species: four adult and one juvenile. Age category was determined according to their body weight. The individual below 90 grams were categorized as juvenile (Smith et al., 1990). All captured pikas were male. Juveniles have similar colour pattern like adults but were brighter than adult. The average morphological measurements were as following as (Table 3).

Table 3: Morphological measurement of captured pika.

Measurement	Adult	Juvenile
Body length (mm)	138.5 ±1.29	108
Hind limb (mm)	62.25 ±0.95	47
Fore limb (mm)	52.5 ±0.57	39
External ear (pinna) (mm)	22.75 ±0.96	22
Whisker length (mm)	102.12 ±0.85	78
Weight (gm)	139.7 ±3.77	84

One dead adult Royle's pika was observed in Thadepati during field survey in July 2011. The cause of death was unknown. It was laying on rock with fresh few petals of flowers on the body (Fig 8).

Figure 8: A. Measurement of *O. roylei* after capture. B. Dead *O. roylei* in Thadepati.

4.1.2 *Ochotona macrotis*

Ochotona macrotis were observed above 3500 masl. They are very swift running and active. They were not observed near human habitat as Royle's pika and not observed in forest habitat. Its pelage colouration was varying with habitat type and seasons (Fig 9).

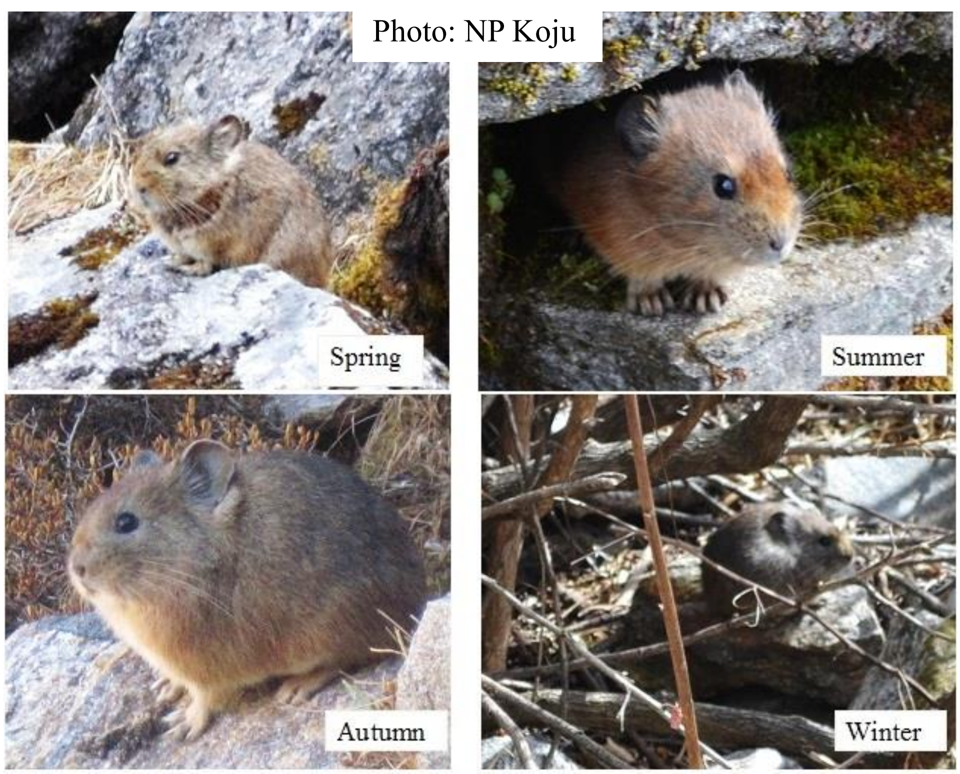


Figure 9: Variation in body colour of *O. macrotis* in different seasons of LNP.

In spring season, general colour of *O. macrotis* ventral side was pale brownish gray with an orange shade. Along the sides of the face, across the shoulders and from the nose over the occipital, the general grayish colour was tinged with rufous. Limbs were of yellowish colour with mixture of white. At the dorsal neck, there was crescent patch of dark yellowish red colour. It might be the emerging sign of sexual maturation to attract opposite sex, as spring is their breeding season.

During summer, its brownish ventral was darker than spring colour and brighter colour at dorsal side. Above the snout in between the occipital, there was reddish brown patch. Near Suryakunda (4789 masl) a juvenile of *O. macrotis* was observed that was different from other juveniles in colour. Its body was completely grayish-white on the dorsal part; ventral was white coloured that continued up to behind the pinna and ventral part of the throat in both limbs. Its frontal was brownish grey and lips were black and shiny black colour around the eyeballs (Fig 10).

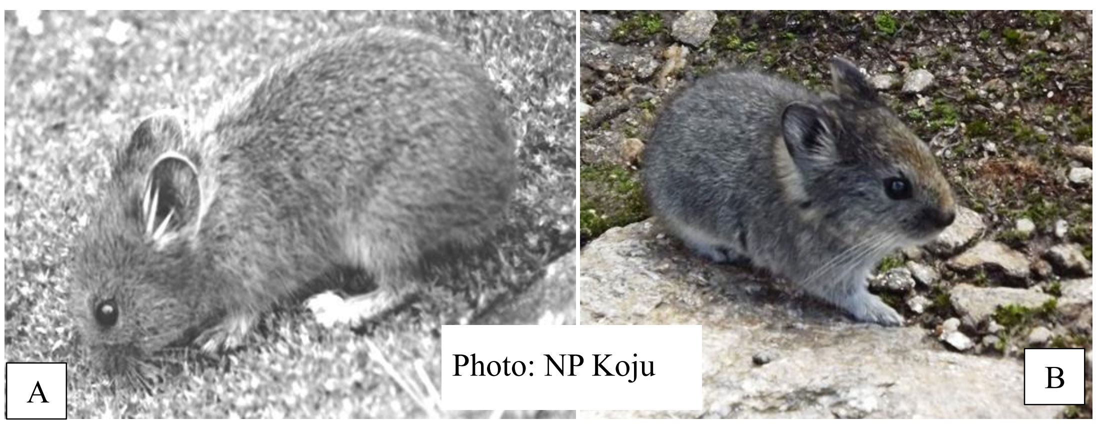


Figure 10: A) Juvenile of *O. roylei* B) *O. macrotis* with thick clad with longer hair inside

In autumn, the body of *O. macrotis* was dense fluffy, pale gray with a tinge of straw yellow. The ventral was darker than the dorsal. Frontal's yellowish patch seems reduced. Outer surface of pinna was grayish yellow but the internal was grayish white. Limbs were grayish too. In winter the dorsal colour observed was mixed with pale, gray, yellowish and black colour while ventral was grayish black. It might be an adaptation against cold climate. *O. macrotis* had longer ear with thick clad in comparison to *O roylei.* The length of whisker was 15 to 18 mm longer in *O. macrotis*.

Total four *O. macrotis* (two in Phedi; July 2012) and one each in Langtang and Lirung glacier area (April 2013) were captured during study period. All of them were adult and male. The average morphological measurement of *O. macrotis* was as follow: body length 152 mm (SD=2.16) mm, hind limb 67.7 mm (SD=1.89), fore limb 60.25 mm (SD=1.7), external ear pinna 26.5 (SD=0.57), the length of whisker was 120.75 mm (SD=1.72) and weight 154.5 gm (SD=3.41).

4.2 Population abundance and distribution

Populations in Langtang were searched from 2800 masl to 5200 masl. Direct and indirect sign method was used to record the presence and absence of pika. The indirect sign; pellets of pika at lowest elevation was observed at 3005 masl at Dimsa near local people's farmland along Gosainkunda route but live pika was not observed there. The evidence of active pikas in Langtang route was recorded from 3018 masl (28°11'47.60"N 85°27'10.51"E) as lowest elevation and was inside the forest of *Quercus semecarpifolia* and rhododendron near Ghodatabela. They were *O. roylei* species. Pikas were observed in three different habitats: in forest and its edge, subalpine area with broken rocks and Alpine area.

4.2.1 Pika population abundance in forest and its edge area

Forest and its edge area started from 2800 masl to below 3500 masl in Gosainkunda route and it was below 3300 masl in Langtang route. This area was below tree line and ten species of trees were found abundant (Fig 11). The frequencies of recorded trees were *Quercus semecarpifolia* (27.02%), *Rhododendron arboreum* (19.39%), *Abies spectabilis* (11.31%), *Betula* species (8.77%), *Pinus roxburgii* (7.85%), *Tsuga dumosa* (7.39%), *Acer* species (maple) (7.16%), *Rhododendron barbetum* (6.93), *Juniperus* species (1.61), *Larix himalaica* (1.39%), *Picea smithiana* (1.15%) and other (5.08%) (N=433). The major shrubs species in that area are *Rosa macrophylla* (16.57%), *Rhododendron lepidatum* (7.91%), *Rhododendron campanulatum* (Chimal) (14.55%), *Berberis* species (20.44%), *Hippophae rhamnoides* (Seabuck thorn) (7.92%), *Daphne bholua* (Lokta) (12.52%), *Lonicera* species. (6.07%), *Piptanthus nepalensis* (8.29%) and others (5.71%) (N=544). *Artemesia vulgare*, *Carex setigera, Danthonia cachemiriana, Fragaria daltoniana, Geranium* species, *Gnaphalium* species, *Moehringia* species, *Polygonum* species, *Rumex nepalensis, Tanacetum parthene, Valeriana* species and Moss are the common ground vegetation.

Royle's pika in forest area were comparatively dark in colour than it inhabits in open area. They were difficult to notice due to camouflage with grass, dry leaves and shadow (Fig 11). Inside the forest, they live in burrows formed in between by rocks. The dominant tress species of this area was Rhododendron. They frequently appeared near the edge of forest for foraging, feeding and musing. They were also observed inhabiting in burrows formed between moss and wall of big rocks.

Figure 11: Pika in forest that camouflage with surroundings. Photo: NP Koju

Total Royle's pika observed in forest and its edge area were 73 in number (mean 7.3± 1.46 and SD 4.62) in ten quadrats during six field studies. The pikas were 16 in 2011 July 10 (2011 October), five (2012 January), 12 (2012 March-April), 14 (2012 July-August) and 16 in 2013 April. Hence, the population density of pika in this area was mean 4.8 individual per ha. Population density in summer was maximum in July 2011 and April 2013 (6.4 individual per ha) and minimum two individual per ha in January 2012. The adult juvenile ratio was 58:15. Juveniles were not observed in winter season.

4.2.2 Pika population abundance in subalpine area with broken rocks

This habitat started from 3500- 3700 masl to 4000 masl in Gosainkunda route and above 3300 masl to 3800 masl in Langtang route. Rocks covered more than 40% of this study area. Pikas live inside these rocks and burrows formed between these rocks. They frequently hide in shrubs for temporary shelter and safety. In that habitat, there were some shrubs and saplings of tree, which were below 3 meters height. The major shrubs were *Berberis aristata* (35.29%), *Rhododendron setosum* (12.13%), *Hippophae rhamnoides* (9.12%), *Rhododendron anthopogan* (8.16%), *Lonicera* species (6.31%), *Rhododendron campanulatum* (5.91%), *Rhododendron lepidatum* (5.22%), *Vibernum* species (4.37 %), *Abies spectabilis* (2.59%), *Juniperus* species (2.04%) and others (8.86%). *Berberis aristata* was widely distributed while others were sparsely in this habitat. *Anaphalis royleana, Bistorta affinis, Euphorbia* species, *Fragaria* species, *Geranium nakaoanum, Kobresia* species*, Plantago brachyphylla, Poa* species, *Polygonum* species, *Primula* species, *Ranunculus* species, *Sterallia alsine, Taraxacum officinale,* fern, lichens and mosses are common ground vegetation.

Total *O. roylei* observed in subalpine rockey area (Fig12) was 182 (mean 18.2and SD = 4.89) with Adult Juvenile ratio 127:55. Population observed in different field survey was 42 (2011 July), 37 (2011 October), 34 (January 2012), 40 (2012 March-April), 34 (October 2012), and 27 in 2013 April for *O. roylei*. The mean population density of *O. roylei* was 12.13 individual per ha. It was maximum in July 2011(16.8 individual) and minimum in April 2013 (10.8 individual).

Figure 12: A**.** *O. macrotis* subalpine area of LNP B. *O. roylei* in subalpine area of LNP.

O. macrotis observed in subalpine rocky area was 144 (mean 14.4± 2.2 and SD 6.96) with 2:1 adult juvenile ratio (Fig 11). Population observed in different field habitat was 53 (2011 July), 10 (2011 October), six (January 2012), 52 (2012 March-April), 34 (July 2012) and

21 in 2013 April. The mean population density of *O. macrotis* in that area was 8.8/ ha and it was maximum in July 2011 (21.2/ha) and minimum in January 2012 (0.8/ha).

4.2.3 Pika population abundance in alpine area

The elevation above 3800 masl in Langtang route and above 3900masl in Gosainkunda route is alpine and talus area. Rocks and boulder covered more than 60% alpine area. Moss and lichens are very common in these rocks. Pikas live insides the naturally occurring burrows formed by these rocks (Fig 13). In such habitat, there were very sparse distribution of shrubs species such as *Rhododendron setosum, Rhododendron lepidatum* and*Berberis aristata.* The ground vegetation composition was contributed by *Apiaceae* species, *Anaphalis* species, *Bistorta* species, *Botrichium* species, *Caltha polustris, Euphorbia* species, *Fragaria* species, *Geranium nakaoanum, Geumelatum, Gramineae* species, *Juncus thomosnii, Jurinea dolomiaea, Kobresia* species, *Ligularia amplllexicaulis, Oxygraphis polypetala, Pedicularis megalantha, Plantago brachyphylla, Potentilla* species, *Primula* species, *Ranunculus* species, *Rosaceae* species, *Salix* species, *Saussurea nepalensis, Selinum tenuifolium, Sibbaldia* species, *Stellaria alsine, Taraxacum officinale, Viola biflora*, moss, lichens and fern species.

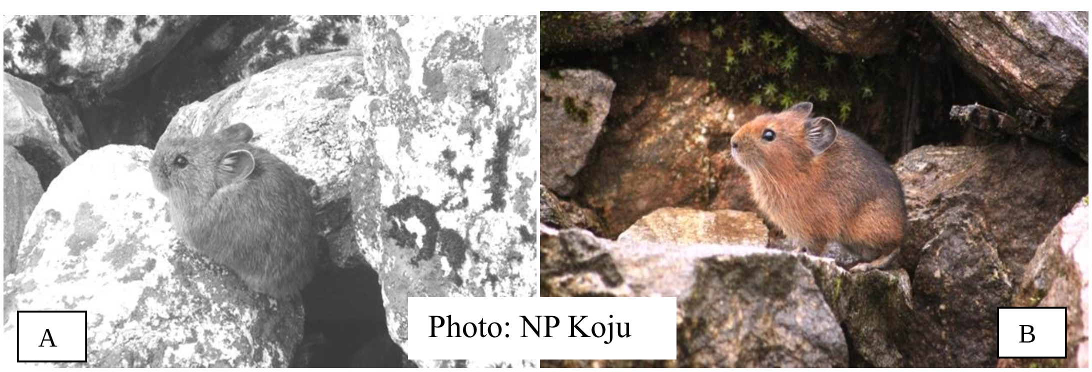


Figure 13: A. *O. macrotis* (Lirung glacier, 4847m) B. *O. roylei* (Ithang, 4232m) in alpine area LNP.

Total 118 *O. roylei* were observed in this area (mean 11.8± 1.95 and SD 6.17) with adult juvenile ratio 81:37. Population of *O. roylei* observed in different field survey was 47 (2011 July), 17 (October 2012), six (January 2012), 14 (March-April, 2012), 24 (July-August, 2012) and 10 in April 2013. Here population density of *O. roylei* was 7.86 (mean), maximum 18.8 individual per ha in July 2011 and minimum 2.4 in January 2012

Total of 157 individual *O. macrotis* were observed (mean 15.7± 2.81 and SD 8.91) with adult juvenile ratio 114:43. They were observed 66 in 2011 July, 14 in October 2012, 11 in January 2012, 21 in March-April, 2012, 28 in July-August, 2012, and 17 in April 2013. The mean population density of *O. macrotis* in alpine talus area was 10.47 individual per ha with maximum 26.4 individual per ha in July 2011 and minimum 4.4 individual in January 2012.

4.2.4 Population density in different season and habitat

Total pika observed was 674 individual (mean 13.18, SD 7.27) in fifty quadrats at six field works. The average density of total pikas was 8.98 individual per ha. The population density of *O. roylei* was 8.28 and *O. macrotis* was 10.03 individual per ha.

The ratio of population density of *O. roylei* in forest and its edge area, subalpine area with broken rocks and alpine area per ha were 7.2/8.8:8.8/10:8/0.8 (along three habitats as ratio of forest and its edge: subalpine area: alpine area) in July 2011, 4.4/0.8:11.6/3.2:6.4/0.4 (October, 2011), 0.8/0:1.6/0:2.4/0 (January, 2012), 5.6/0:13.6/0:5.6/0 (March-April, 2012), 8.4/4.8:10/6:5.6/4 (July-august, 2012) and 2.8/0.4:6.8/4:3.6/0.4 in April 2013 (Fig 14).

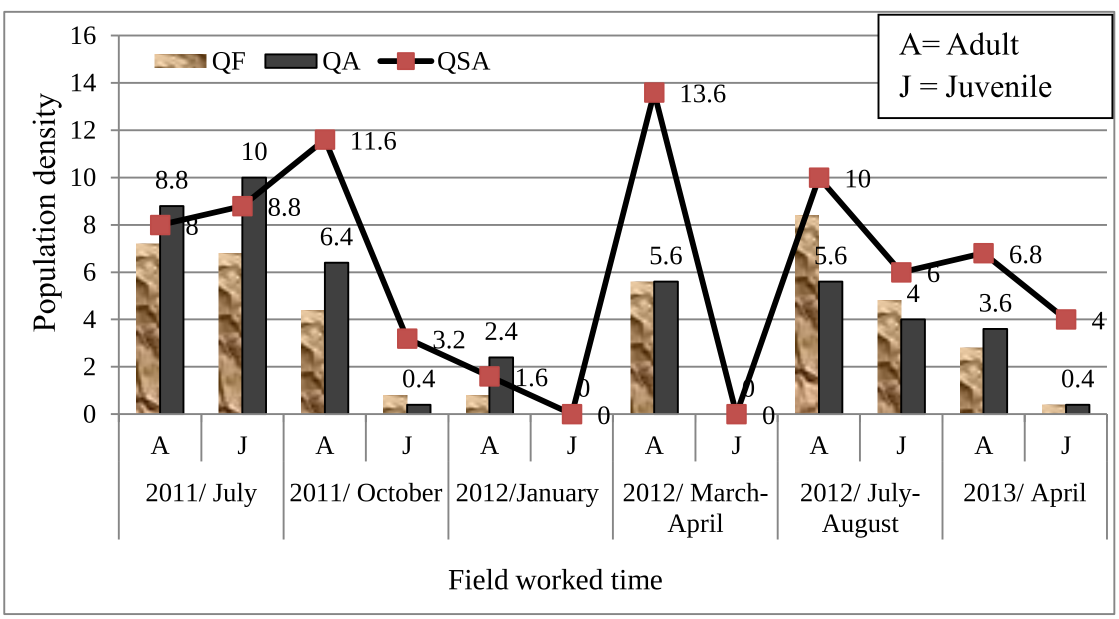


Figure 14: Comparative population density of *Ochotona roylei* in different habitat and seasons.

The highest population density of adult *O. roylei* was in 2012 March – April (13.6/ha) in Alpine area and least was in 2012 January (.08/ha) in forest area. Juvenile *O. roylei* were observed maximum in 2011 July in Alpine area but they were not recorded in winter. The correlation between elevation and population of *O. roylei* was 0.066314 and the slope equation was $y = 0.0003x + 1.0084$ with $R^2 = 0.0044$. There is no any significant relation between elevation and population distribution of Royle's pika in Langtang National Park (P value =0.376, df = 179)

Similarly, the ratio population density ratio of *Ochotona macrotis* in subalpine area with broken rock and alpine area was 14/12.4:10.8/10.4 in July 2011, 5.2/0.4:3.6/0.4 (October 2011), 2/0:1.6/0 (January 2012), 4.4/0:5.4/0 (March-April, 2012), 7.2/4:12.8/6 (July-august, 2012) and 6.4/0.4:8.6/1.2 per ha in April 2013 (Fig 15). Adult *Ochotona macrotis* were observed highest density in 2011 July (14/ha) in alpine area and least in 2012 January both in alpine and subalpine area (0.4/ha). Juvenile *O. macrotis* were recorded highest in alpine area 2011 July (12.4/ha). They were not observed in winter. The correlation between elevation and population of large eared pika was 0.018573 with slope trend $y = 0.0001x + 1.9077$ with $R^2 = 0.0003$. There is no any significance between elevation and population distribution of *Ochotona macrotis* (P value is .084, df =119)

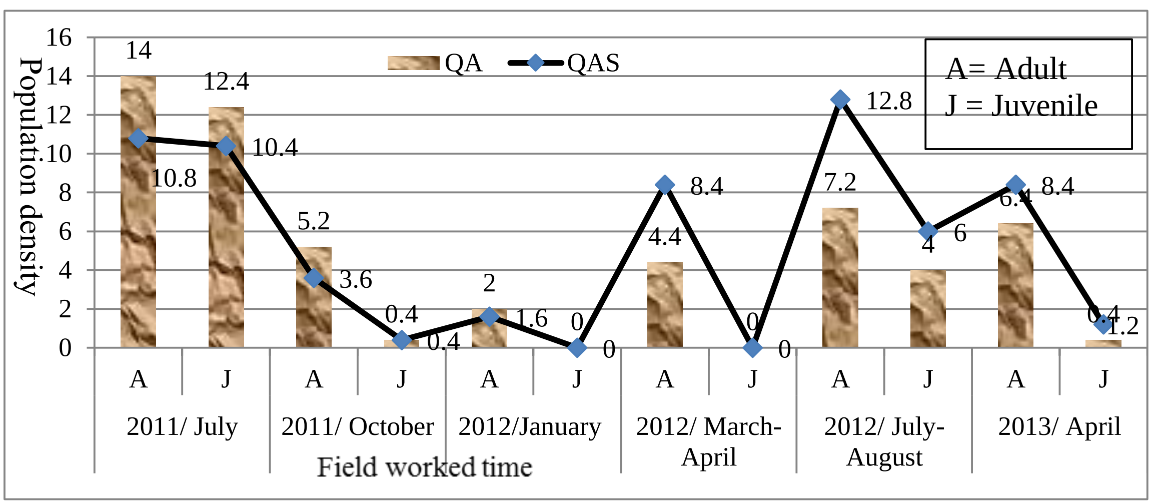


Figure 15: Comparative population density of *Ochotona macrotis* in different habitat and seasons.

For further statistical analysis one-Sample K-S Test was done with one species in one kind of habitat but in different seasons that obeyed normal distribution (p>0.05); similarly paired-samples to test was done to compare the number of individuals in two kinds of habitats (subalpine and alpine since there was no *Ochotona macrotis* in forest and its edge area). This test shows there is no significant relation (t=-0.365, df=5, p=0.730) between population distribution in subalpine area and alpine area, even comparison between adult with adult has t=-0.691, df=5, P=0.521 and juvenile with juvenile had t=0.450, df=5, P=0.671. In all aspect P value is greater than 0.005 so, there no significance between population and habitat type for pika species.

However, for *O. roylei*, the number of this species in forest area was significantly smaller than in subalpine area (t=-3.722, df=5, p=0.014), and when considered only adults and juveniles, similar result came out (for adult: t=-2.962, df=5, p=0.031; for juveniles: t=-2.613, df=5, p=0.048). The population distribution of *O. roylei* was less in forest and its edge habitat and when habitat changes to open area with broken rocks, its population abundance was increased. However, its population abundance had again no significance between subalpine area and alpine area (for adult: t=2.230, df=5, p=0.076; for juveniles: t=1.567, df=5, p=0.079). This shows there no significance relation between habitat type and population as well as no significance between habitat and population of different age category and species. The exception was population of *O. roylei* that was significantly smaller in forest and its edge in comparison to other habitats. Thus, the pika prefer alpine, subalpine with more rocks area for its habitat.

The total population of pika observed along attitudinal gradient shows pikas' population was concentrated in elevation range of 3600 to 4000 masl (41.11%) Only 3.2% of total observed pika inhabit at altitudinal range of 4000 - 4200 masl (Fig 16).

The correlation between elevation and total pika population observed in 50 quadrats (30 for *O. roylei* and 20 for *O. macrotis* in respective 3 habitats) in six field visits is 0.0636 with p value of 95% significance level of 0.271, df 299. This indicates there is no significance and correlation between elevation and total population. Similarly, further analysis was done to establish correlation between population abundance and elevation: Durbin-Watson Statistic = 1.2359, the value of Normality Test p value = 0.0046, K-S Statistic = 0.1288 with Significance Level = 0.0046, for Constant Variance Test p =

<0.0001, which is again failed to show significance relation between total population and population distribution.

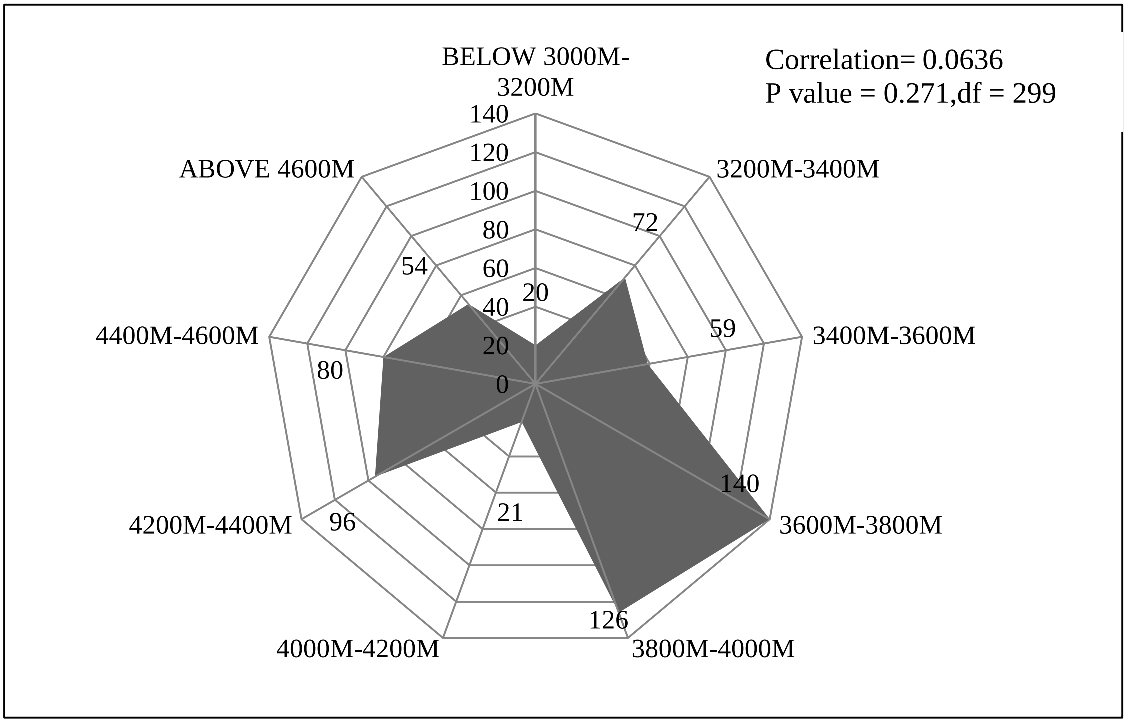


Figure 16: Total pikas population observed in different altitudinal gradients in LNP.

4.3 General Behaviour

The behaviour of both species pika was observed and recorded by using focal scan sampling in time interval of 1 minute. Behaviour of pika was observed from 5:30 to 19:30 during summer and from 6:30 to 17:30 during winter. Behaviours were observed approaching close to pika (Fig 17) as well as using binocular from vantage point.

Annual recorded behaviours were divided into two seasonal behaviour- summer and rainy season (from April to September) and winter season (October to March). Behaviours of *O. macrotis* were observed for 294 hours in summer and 165 hours in winter. External behaviour was recorded for 186.16 hours (63.32% of total time) and 18.38 hours (11.14%) respectively in that period.

Figure 17: Close observation of behaviour of pika by researcher, LNP.

Similarly, behaviour of *O. roylei* was recorded 202 hours and 23.55 hours with the percentage of activeness 68.98% and 14.27% respectively in summer and winter season (Table 4). Pikas were active during dawn and dusk. They were not active outside the burrow in heavy rain. In general, they were active and fast moving. They use multiple numbers of burrows temporarily during foraging and feeding.

Table 4: Total time budget in minutes of pika with their age group according to season in LNP.

Season	Pika	Groom	Muse	Feed	Forage	Chase	Call	IB	Gallop	Total
Summer	AOM	901	2472	2246	1973	89	72	1508	496	9757
	JOM	182	236	289	404	31	9	151	111	1413
Winter	AOM	134	576	74	85	0	0	234	0	1103
Summer	AOR	897	2163	2343	1884	75	89	1166	359	8976
	JOR	241	566	932	788	20	27	485	133	3192
Winter	AOR	193	648	165	161	0	4	231	11	1413
Total (in min)		**2537**	**6249**	**6173**	**5538**	**246**	**206**	**3695**	**1210**	**2585**
Total (in hr)		**42.28**	**104.1**	**102.8**	**92.3**	**4.1**	**3.43**	**61.5**	**20.16**	**430.9**
Percentage (%)		**9.81**	**24.17**	**23.87**	**21.42**	**0.95**	**0.79**	**14.2**	**4.68**	**100**

Note: AOM= Adult *O. macrotis*, JOM = Juvenile *O. macrotis* juveniles,
AOR = Adult *O. roylei* and JOR = Juvenile *O. roylei*

During summer, adult *O. macrotis* spent their 25.34% time in musing, 23.02% in feeding, 20.22% in foraging while other activities such as inside burrow (15.45%), grooming (9.23%), galloping (5.084%), chasing (0.912%) and calling (0.74%) was performed among total time of 9,757 minutes. In winter those behaviour of adult *O. macrotis* were 52.22% in musing, 6.71% in feeding, 7.71% in foraging, 21.21% in inside burrow and 12.15% in grooming among total time of 1,103minutes. There was absence of galloping, chasing and calling behaviours in winter. The juvenile of *O. macrotis* were not observed in winter, their external time budget in summer was 28.59% in foraging, 20.45% in feeding, 16.70% in musing, 12.88% in grooming while other activities such as inside burrow (10.69%), galloping (7.86%), chasing (2.2%) and calling (0.64%) in total time of 1,413 min (Fig 18).

Ochotona macrotis spent their maximum time of summer in musing (24.09), feeding (26.1) and foraging (20.98) but in winter musing behaviour was observed the most (52.22%); it was more than the sum of other all behaviours. Juveniles show more chasing behaviour (2.20%) than adult (0.912%) does. The range of grooming behaviour (9.23%- 12.88%) was similar in adult and juvenile in both seasons. Adult *O. macrotis* shows very less external activity in feeding and grooming in winter with comparison to summer. During winter most of the outer surface was covered by snow. Sometime *O. macrotis* were observed feeding lichens and roots of dry shrubs and small trees.

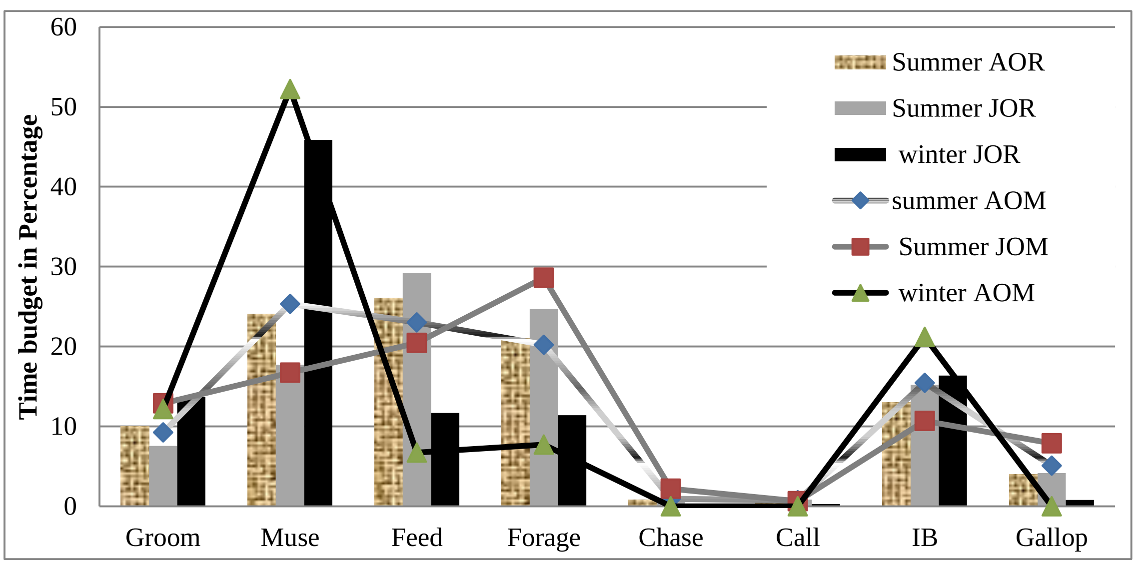


Figure 18: Age-wise seasonal time budget in percentage of *O. roylei* and *O. macrotis.*

Note: AOM= Adult *Ochotona macrotis*, JOM = Juvenile *O. macrotis* juveniles, AOR = Adult *O. roylei* and JOR = Juvenile *O. roylei*

The adult *O. roylei* observed 26.10% of time in feeding behaviour, then musing (24.10%), foraging (20.99%), inside burrow (12.99%), grooming (9.99%), galloping (4.01%), calling (0.99%) and chasing (0.84%) (N=8976minutes) in summer. In winter adult *O. roylei* had external time budget 45.86% in musing, and other behaviour such as inside burrow (16.34%), grooming (13.66%), feeding (11.40%) foraging (2.19%), galloping (0.78%) and calling (0.28%) (N=1413 minutes). Chasing was not recorded in winter. The juvenile of *O. roylei* was not observed in winter. The external time budget in percentage of juvenile *O. roylei* in summer was 29.19% (feeding), 24.68% (foraging), 17.73% musing), 15.19% (inside burrow), 7.55% (grooming), 4.17% (galloping), 0.85% (chasing) and 0.63% (calling), (N=3192 minutes) (Fig 17).

4.3.1 Comparison between *O. roylei* and *O. macrotis* behaviours

Total behaviour observation time for adult *O. macrotis* was 181 hours. In this time external time budget of adult was 3,048 minutes in musing, 2,320 minutes in feeding, 2,058 in foraging while other behaviour such as inside burrow (1,742), grooming (1,035), galloping (496), chasing (89) and calling (72) recorded. Similarly, the activities of adult *Ochotona roylei* were observed for 173.15 hours. During this time of observation, its feeding was observed the most for 2,632 minutes. It was followed by musing (2,399), foraging (2,288), inside burrow (1,317), grooming (1,079), galloping (470), chasing (106) and calling (98) (Table 5).

Table 5: Total time budget of Adults *O. roylei* and *O. macrotis* in different behaviours in LNP.

Pika species	**Behaviours**								**Total**
	Groom	**Muse**	**Feed**	**Forage**	**Chase**	**Call**	**IB**	**Gallop**	
O. macrotis	1035	3048	2320	2058	89	72	1742	496	10860
O. roylei	1079	2399	2632	2288	106	98	1317	470	10389

The t-pair test (using R software) between behaviours with *O. macrotis* and adult *O. roylei* gives p-value = 0.3712 (t = 0.9473, df = 8), which shows no significant difference between total behaviours. The behaviour pattern of adult *O. macrotis* and adult *O. roylei* were similar.

Juveniles of *O. macrotis* were observed for 1413 minutes in summer as they were not observed in winter. In this time budget the behaviours for foraging was the highest (404 minutes) it was followed by feeding (289), musing (236), grooming (182) and calling (9) was the least (Table 5). Similarly, Juveniles of *O. roylei* was observed for 3192 minutes and their time budget for feeding was highest (932 minutes). It was followed by foraging (788), musing (566) and least was chasing (20) (Table 6).

Table 6: Total time budget of Juveniles of both species in different behaviours in LNP.

Pika species	Behaviours								Total
	Groom	Muse	Feed	Forage	Chase	Call	IB	Gallop	
O. macrotis	182	236	289	404	31	9	151	111	1413
O. roylei	241	566	932	788	20	27	485	133	3192

When the t-pair test between behaviour of these juveniles with their total external time budget was calculated, the p-value = 0.0686 ((t = 2.1031, df = 8), which shows there is no significant difference on behaviour of juveniles. The behaviour pattern of juveniles of *O. macrotis* and juveniles of *O. roylei* were similar.

Among the total behaviour (including adult and juvenile) of *O. macrotis* grooming was observed 9.91%, while musing 26.76%, feeding 21.26%, foraging 20.06%, chasing 0.97%, calling 0.65%, inside the borrow 15.42% and galloping observed 4.945% in total time of 12273 minutes (204.55hr) (Table 7).

Table 7: Percentage of total time budget in percentage of both age groups.

Pika species	Behaviours								Total
	Groom	Muse	Feed	Forage	Chase	Call	IB	Gallop	
O. macrotis	9.91	26.76	21.26	20.06	0.97	0.65	15.42	4.945	12273
O. roylei	9.71	21.83	26.24	22.64	0.92	0.92	13.26	4.44	13581

The total behaviour observed (including adult and juvenile) for *O. roylei* was 13581 minutes (226.35hr). Among the recorded different behaviours the highest percentage was observed for musing (26.24%), feeding (21.26%) and foraging (20.06%) while lower percentage was observed for chasing (0.97%) and calling (0.65%).

The t-pair test result between these two variables (behaviours of *O. macrotis* and *O. roylei*) had no significant difference in Langtang National Park (p-value = 0.9986).

4.3.2 Comparison between seasons

The behaviour of *O. macrotis* was observed in summer for 9,757 minutes (162.61hr). This time budget was 25.33% in musing, 23.01% feeding, 20.22% foraging, 15.45% inside burrow, 9.23% grooming, 5.08% in galloping, 0.91% chasing, and 0.73% calling. Both species of pika were observed very less activities in winter in all the elevations and habitats. They were mostly observed musing (basking sun) and the major activities like feeding and foraging were very less during winter (Table 8). In winter, the observation time was just 1,103 minutes (18.38hr). The external time budget was 52.22% for musing, inside burrow (21.21% and grooming (12.14%). There was no record of chasing, calling and galloping of *O. macrotis* in winter season (Table 7).The t-pair test between behaviours of adult *O. macrotis* in different season shows significance different in their behaviour according to season (p value = 0.00845; t = 3.6253, df = 7).

Table 8: Comparative season wise behaviour of adult *O. macrotis* in percentage.

Season	**Behaviours**							
	Groom	**Muse**	**Feed**	**Forage**	**Chase**	**Call**	**IB**	**Gallop**
Summer	9.23	25.33	23.01	20.22	0.91	0.73	15.45	5.08
Winter	12.14	52.22	6.70	7.70	0	0	21.21	0

Similarly, data were collected for *O. roylei* and its behaviours were observed for 8,976 minutes in summer and 1,413 minutes (23.55hr) in winter. Their external time budget was 26.10% in feeding, 24.09% in musing, 20.98% foraging, 12.99% inside burrow, 9.99% grooming, 3.99% galloping, 0.99% calling and 0.83% chasing in summer (Table 9).

In winter *Ochotona, roylei* spent the external time budget as 45.85% in musing, 13.65% in grooming, 11.67% in feeding, 11.39% in foraging, 16.34% inside burrow, 0.77% in galloping and 0.28% in calling. No chasing was recorded in *O. roylei* in winter as in *O.*

macrotis (Table 8). The t-pair test between behaviours of adult *O. roylei* in different season shows the significant different with p-value = 0.01164 (t = 3.3875, df = 7).

Table 9: Comparative season wise behaviour of Adult *O. roylei* in percentage.

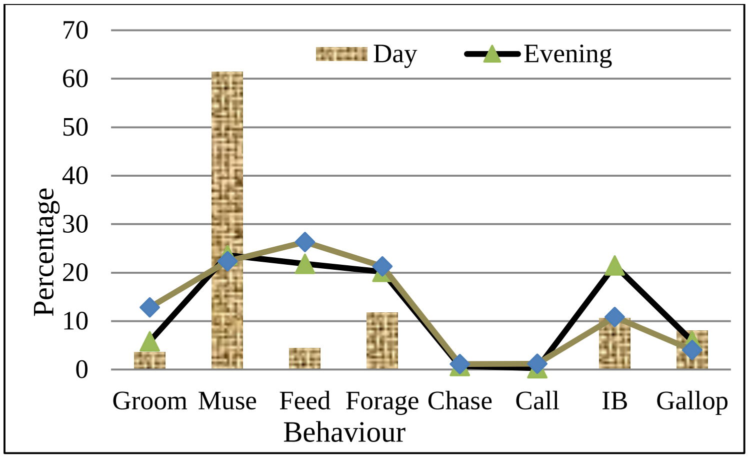
Season	Behaviours							
	Groom	Muse	Feed	Forage	Chase	Call	IB	Gallop
Summer	9.99	24.09	26.10	20.98	0.83	0.99	12.99	3.99
Winter	13.65	45.85	11.67	11.39	0	0.28	16.34	0.77

4.3.3 Shift wise behaviour

During the field observation, the behaviours of both pikas species were observed diurnally from 5:30 AM to 7:30 PM in summer and 6:30 AM to 5:30 PM in winter. This diurnal time was divided into three categories: morning, day and evening (afternoon) shift to analyze the behaviours to time specific. Morning shift was from 5:30 (6:30 in winter) to 10 AM, day shift was from 10 AM to 3 PM and evening shift was 3PM onward. Pikas' external activities were more from early morning before sunlight touch the ground to around 10 AM. After 10 AM, their external activities decreases, very few individual were observed during late morning and daytime in all seasons' field study. However, around 3 PM onward their external activities increases and were observed active even after sunset before pitch dark.

4.3.4 Shift wise behaviour of *O. macrotis*

The adult *O. macrotis* spent its maximum time in feeding (26.32%) during morning shift of summer season. It was followed by musing (22.32%) and foraging (21.27%). Their time budget was the least for chasing (1.15%) and calling (1.19%) (N=4931). During daytime, they were observed only for 610 minutes in total study period. Out of these times, pikas were observed musing for 61.45% of time. They were not observed chasing and calling (Fig 19). They spent less time for foraging (11.8%), inside burrow (10.61%) (N=4216). They were not seen active in feeding, the feeding behaviour was recorded only 4% of total time budget. In afternoon and evening shift they were found to spent majority of time in three behaviours such as musing, (21.85%), feeding (21.51%) and foraging (20.2%). Calling was the least (0.3%) recorded behaviour during evening shift.



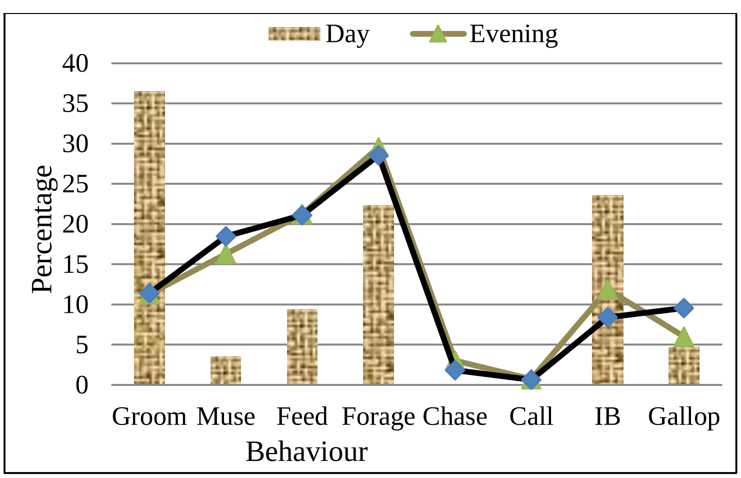
Time budget in minutes

Shift	**Mor.**	**Day**	**Even.**
Groom	632	22	247
Muse	1101	375	996
Feed	1298	27	921
Forage	1049	72	852
Chase	57	0	32
Call	59	0	13
IB	536	65	907
Gallop	199	49	248
Total	**4931**	**610**	**4216**

Figure 19: Shift wise time budget of adult *O. macrotis* in summer.

The Juvenile *O. macrotis* spent its maximum time in foraging (28.57%) during morning shift in summer (Fig 20). It was followed by feeding (21.1%) and musing (18.47%). Their time budget was the least for calling (0.6%) and chasing (1.81%) (N=763). The calling of juvenile was recorded during chasing each other. This calling seems to be the response of play/aggressive output, which was heard differently from adult alarm call.

During daytime, they were observed only for 85 minutes. In this, period pikas groomed for 36.47% of total time budget. They were not observed chasing and calling. The musing feeding and galloping was less than 5%. They spent 23.03% of daytime inside burrow. In evening shift, they spent maximum time in feeding (21.23%) and foraging (29.55%). They were observed 67 minutes insides burrow. They chased for 17 minutes and calling was the least observed behaviour (0.7%) during evening shift (N=565).

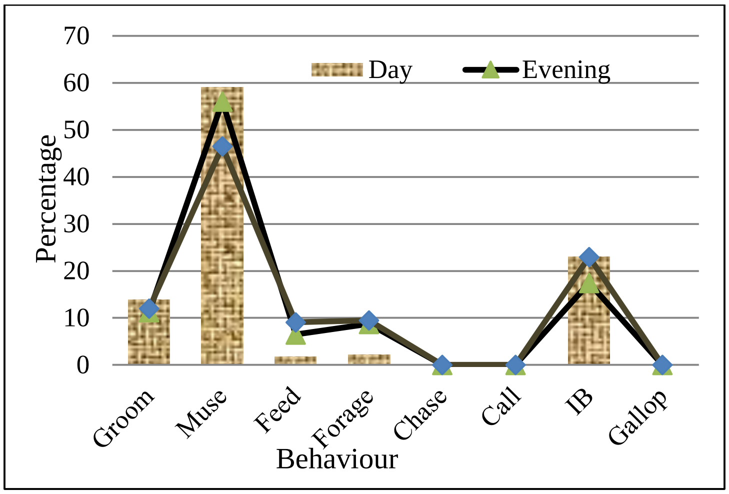


Time budget in minutes

Shift	**Mor.**	**Day**	**Even**
Groom	87	31	64
Muse	141	3	92
Feed	161	8	120
Forage	218	19	167
Chase	14	0	17
Call	5	0	4
IB	64	20	67
Gallop	73	4	34
Total	763	85	565

Figure 20: Shift wise time budget of Juvenile *O. macrotis* in summer.

The adult *O. macrotis* was not observed making any call, galloping and chasing each other in winter during study period. They were calm and less active during winter. They were observed musing and can be notice easily when they move to enter burrow or by motion while grooming. In morning shift of winter, adult *O. macrotis* spent 46.52% time budget in musing (Fig 21).



Time budget in minutes

Shift	**Mor.**	**Day**	**Even**
Groom	62	32	40
Muse	241	136	199
Feed	47	4	23
Forage	49	5	31
Chase	0	0	0
Call	0	0	0
IB	119	53	62
Gallop	0	0	0
Total	518	230	355

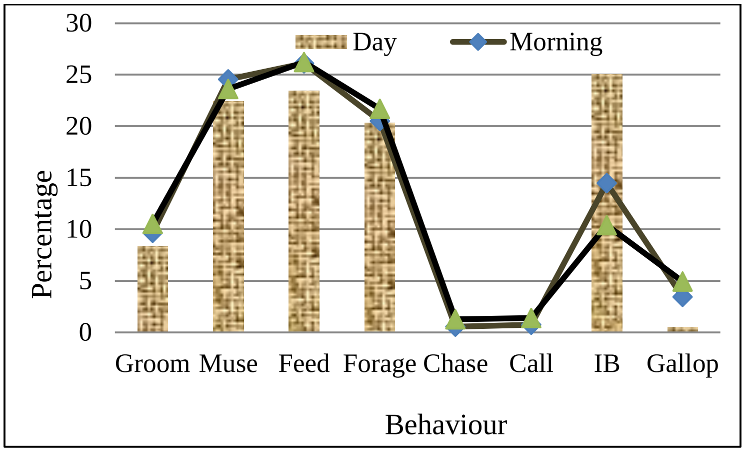
Figure 21: Shift wise time budget of adult *O. macrotis* in winter.

It was followed by inside burrow (22.97%), grooming (11.96%), and foraging 9.46% and feeding (9.07%) (N=518). During day shift they were observed for 230 minutes of total observation time which they spent 59.13% in musing (basking sun). They enter burrow (23.04%) frequently and groom while outside (13.91%) during basking. Feeding and foraging behaviour was less than 3%. In afternoon/evening shift, adult *O. macrotis* spent its majority of time in musing (56.05%) as in other shift. It was followed by inside burrow (17.46%), grooming (11.26%) foraging (8.73%) and feeding (6.45%) (N=355). They were observed feeding on bark of rhododendron and other dry shrubs. Some of them were observed feeding on roots of shrubs and herbs also.

4.3.5 Shift wise behaviour of *O. roylei*

In summer morning, adult *O. roylei* spent its maximum time budget in feeding (26.11%) which was followed by musing (24.53%), foraging (20.49%), inside burrow (14.48%), grooming (9.65%) and gallop (3.4%). The chasing and calling behaviour was less than 1%

(N=5005 minutes). During day shift adult *O. roylei* were not observed making call and chasing (Fig 22).



Time budget in minutes

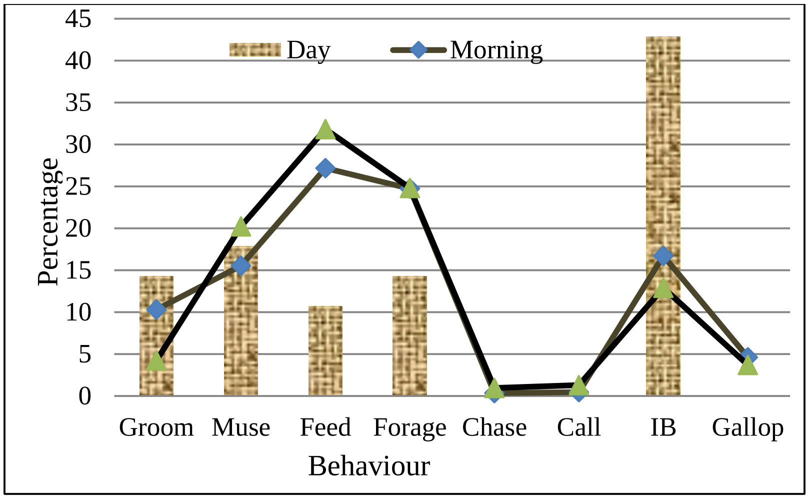
Shift	**Mor.**	**Day**	**Even.**
Groom	483	16	398
Muse	1228	43	892
Feed	1307	45	991
Forage	1026	39	819
Chase	27	0	48
Call	37	0	52
IB	725	48	393
Gallop	172	1	186
Total	5005	192	3779

Figure 22: Shift wise time budget of adult *O. roylei* in summer.

The maximum time budget was for inside burrow (25%) which was followed by feeding (23.43%), musing (22.39%) and foraging (20.31%). They groom for 8.33% and gallop less than 1% of total dayshift time budget (N= 192). Adult *O. roylei* was active in feeding in afternoon/evening shift too. They spent 26.22% of time in feeding which was followed by musing (23.6%), foraging (21.67%), grooming (10.53%), inside burrow (10.39%), galloping (4.92%), chasing (1.27%) and calling (1.37%) (N=3779).

Morning shift of juvenile *O. roylei* has maximum time budget in feeding (27.18%). It forage for 24.74%, inside burrow is 16.73% followed by musing (15.54%), grooming (10.32%) and galloping (4.62%). The total chasing and calling behaviour is less than 1% (N=1685 minutes).In day shift observation of juvenile *O. roylei* was very rare. They were observed just for 28 minutes in all field study period (Fig 23).

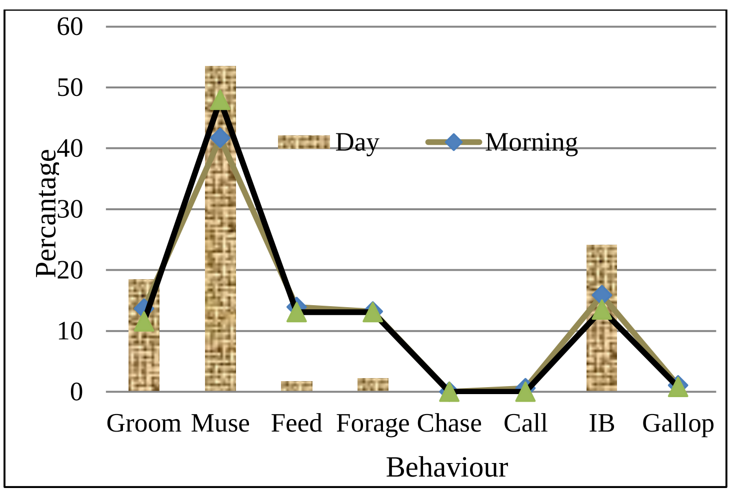
During that period, they were seen inside the burrow for 42.85% with very less external activities. They were observed 17.85% musing, 14.28% grooming and foraging, just 10.71% for feeding. There was no single call, chasing and galloping observed during day. In evening session juveniles were again active in feeding (31.84%), foraging (24.81%), musing (20.21%), inside burrow (12.91%), grooming (4.25%), calling (1.28%) and chasing 0.94% (N=1479). Here chasing in juveniles were like playing between two juveniles. They travel long distance and ran through multiple burrows like hide and search while chasing.



Time budget in minute			
Shift	**Mor.**	**Day**	**Even**
Groom	174	4	63
Muse	262	5	299
Feed	458	3	471
Forage	417	4	367
Chase	6	0	14
Call	8	0	19
IB	282	12	191
Gallop	78	0	55
Total	1685	28	1479

Figure 23: Shift wise time budget of Juvenile *O. roylei* in summer.

In winter, adult *O. roylei* spent its maximum time in musing in all shifts of a day (41.69%, 53.5% and 47.94% respectively). Chasing was not observed during winter observation period and only four calls (0.59%) was heard in morning (N=674). The calling behaviour in winter was only recorded from *O. roylei* (Fig 24).



Time budget in minute			
Shift	Mor.	Day	Even.
Groom	92	42	59
Muse	281	122	245
Feed	94	4	67
Forage	89	5	67
Chase	0	0	0
Call	4	0	0
IB	107	55	69
Gallop	7	0	4
Total	674	228	511

Figure 24: Shift wise time budget of Adult *O. roylei* in winter.

Royle's pika spent its second most time budget of winter in grooming activity in all shifts which were 13.64% in morning (N=674), 18.42% in day (N=228) and 11.54% in evening (N=511). The time budget for feeding and foraging for both morning and evening shift was around 13% and they were observed feeding (1.75%) and foraging (2.19%) very less in day shift. There was no observation of galloping in daytime. Pikas were less active in movement and other external activities in winter. They preferred musing or sun basking during winter season with average 47.71% of total time in a day.

4.3.6 Comparison on grooming behaviour

Pikas (combining both species) were observed grooming 9.81% of its external time budget. The grooming was done in three ways; grooming by using hind limb, grooming by fore limb and grooming by mouth (self-biting). Groomed by other individual was not observed. Proportionately of using mouth, hind limb and forelimb had similar value. Pika used its forelimb to groom around facial part like cleaning face. Face was groomed gently not by nail of fingers but by its fingers and palm. They cleaned mouth and facial parts frequently. Hind limbs were used to groom around head and neck region. Right hind limb was used to clean right part of the body and left for left side. Mouth was used to groom behind neck part at ventral side and all around the dorsal side (Fig 25).

Figure 25: Pika grooming in different parts of body: A. by forelimb B. by mouth

Grooming was cleaning process in pika. Most frequent grooming shows pika clean organism, and have more ecto-parasite (!). However, flea or lice were not recorded in any captured pika. They self-groomed (auto grooming) in all shifts and all season. The highest grooming was recorded in 8 Am (321 minutes) and 8:30 AM (318 minutes). In total grooming time, morning interval had maximum grooming, 35.9% of total grooming was observed in interval of 7AM to 9 AM (Fig 26). The least grooming behaviour was recorded at 10:30 (2 minutes) and 11:30 (4 minutes) in day shift. The period between 17 PM to 19 PM had the middle range of grooming (56 – 156 minutes). This interval occupied had 19.89% of total grooming activities. The grooming behaviour was highest at 17:30, evening

(156 minutes) at the time of sunset. The frequency of grooming decreases after sunset in evening shift.

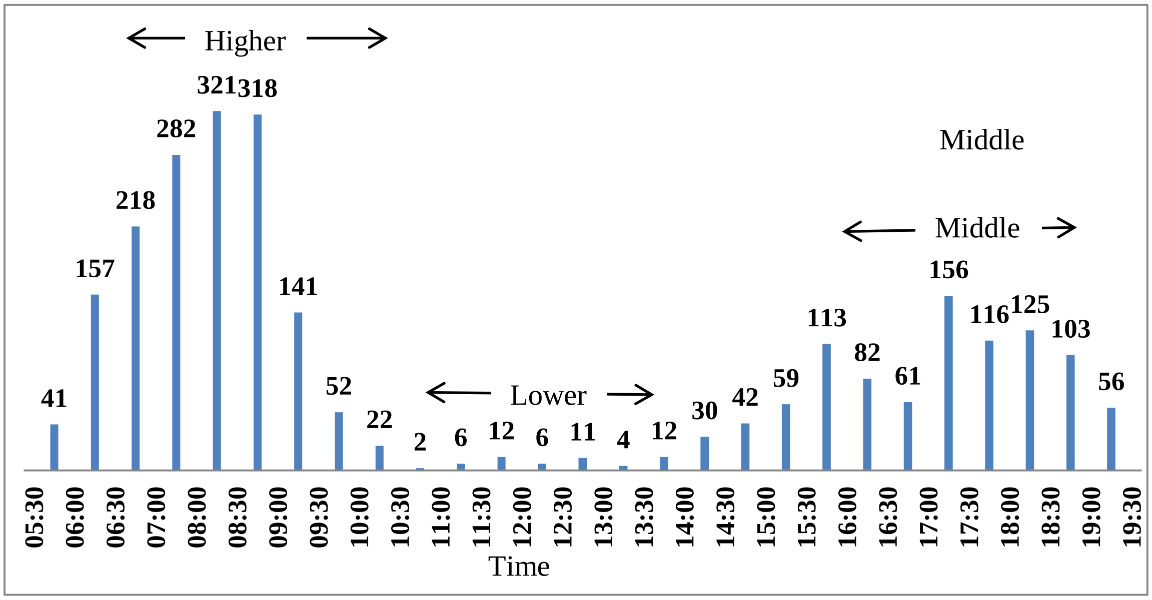


Figure 26: Pika grooming frequency (in minutes) and time of grooming in a day.

4.3.7 Comparison of musing behaviour

Musing is resting on the stone or big rock or open ground for long time being motionless. Musing is significant behaviour of pika; because of this behaviour, people in Langtang area respect pika as symbol of Buddhist monk. They called it "Bhragomjin", which means rabbit that lives in stone. Local people believe that pika is peace-loving animal and have spiritual power of control on rain, wind, snowing and lightening. Pikas were alert and paying attention to movement around its sitting place while musing.

They muse near their burrow at vantage point. They were not observed closing eye while musing. Two or more were found pika musing on a single rock with the gap of less than 1-2 meter but their sex and social structure was not clearly understood (Fig 27). Royle's pikas in subalpine area were comparatively habituated to people. They were observed frequently musing around people's huts, cowshed, hotel and people working area.

Adult *O. macrotis* in winter was recorded as the highest muse (52.22%) among its total time budget. Similarly, adult *O. roylei* in winter muse for 45.85% of its external behaviour. The least time budget for musing was of juvenile *Ochotona macrotis* in summer (16.70) and juvenile of *O. roylei*

(17.73%). The records of behaviour shows adult pika muse in more frequency than juvenile and they muse more in winter than summer.

Figure 27: Two pikas close to each other musing nearby peoples' hut and wood chopping area, LNP.

Pikas were observed musing in all season and all time shifts. They spent 24.17% of total external time budget in musing. In daytime shift, more than 50% of their time budget was in musing in both species and age category. Musing was especially observed in sunlight so, this is like sun basking behaviour (Fig 28).

Figure 28: Pika musing in different habitat of LNP.

However, pikas were very often observed musing even there is no sunlight and breezing cold wind. Musing extends from very short (less than 1 minutes) to long musing (more than 15 minutes continuously). They were observed most of the time musing for short time and one of the longest musing records was 22 minutes by a Royle's pika juvenile in

Laurebina in July 2011. It was musing near rock wall of a hotel at evening shift. The concentration of musing behaviour was in between 9 AM to 10 AM in morning shift and 17 PM to 18:30 PM in evening shift (Fig 29). The musing time increases after sunrise and sun light covering in pika habitat in morning and it was again increased near sunset. Pika very often grooms while they were musing and calling; long call was performed during this situation.

Musing range was higher (536-867 minutes) at 9:00 10:00 morning and 17:30 to 18:30 at evening. In morning shift the musing behaviour was in middle range (302 to 429 minutes) and pikas were observed less range 28 -157 minutes) in day shift.

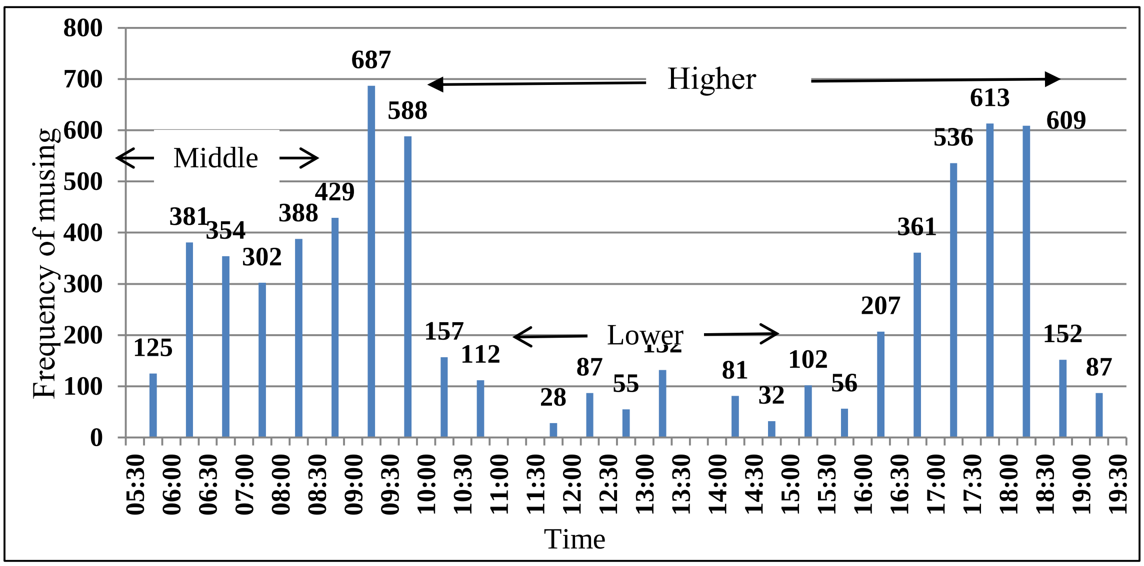


Figure 29: Diurnal musing frequency (in minutes) and time of musing of pika.

4.3.8 Comparison between chasing and calling behaviour

Calling is major characteristic behaviour of pika. The name pika was originated by its long and sharp calling behaviour. The calling behaviour of both species in Langtang National park was not as significant as it was described in other species in different places of the world. Total calling was herd 206 times in 25854 minutes observation. Among calling, *O. macrotis* were observed and listened for 81 times and *O. roylei* for 116 times. No calls were heard in winter except four calls by *Ochotona roylei* at Phedi (sub-alpine area).

There were two types of calling short call "chi chi' and long call 'Chirrr…rrr'. Long call was made while they were musing and short call was most frequent while chasing. Long calls were easily heard from distance but short calls were hard to detect. Long calls were like alarming call but response such as hiding or running after long call were not observed. Juveniles of both species were observed making very less calling. *O. macrotis* made more calling in morning shift while adult *O. roylei* made calling more in evening shift. No calling were heard in daytime (Fig 30).

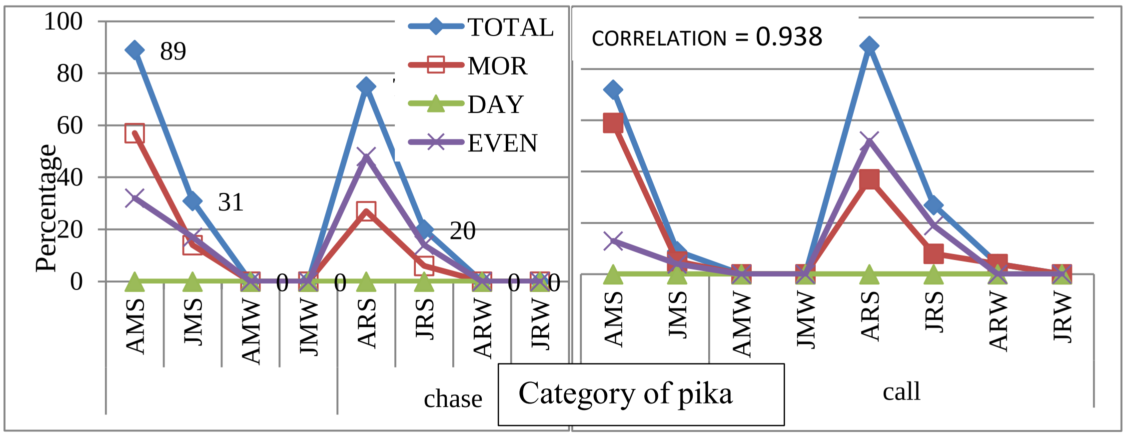


Figure 30: Comparison between chasing and calling between two species of pika in LNP.

Note: In figure AMS = adult *O. macrotis* in summer, JMS = juvenile *O. macrotis* in summer, AMW = adult *O. macrotis* in winter, ARS = adult *O. roylei* in summer, JRS = juvenile *O. roylei* in summer, MOR = Morning and EVEN = Evening

Chasing was play like behaviour most often performed by the juveniles. Adults chase too, adult chased to both adult and juvenile but fight or biting between them were not observed. Chasing by adult-to-adult was not likely to territorial behaviour: in some incidents, chasing leads to mating. While chasing they run long distance passing through multiple burrows. Total 246 chasing incidents were recorded in 25,854 minutes, which was less than one percent of total time budget.

Chasing behaviour was not observed in winter season in both species of pika. As calling (Fig 30) chasing behaviour was recorded more in morning shift in *O. macrotis* and in evening shift for *O. roylei*. Pika made call while chasing (most often) statistically the calling and musing behaviour had correlation of 0.938, it means the chasing behaviour and calling behaviour were highly correlated to each other. During field study, none of the pikas was observed fighting, but some close individual photographs of pikas shows they had fighting evidences. The tore earmarks, visible sign of wound at nose and mouth seems to be the impact of fight among pikas (Fig 31).

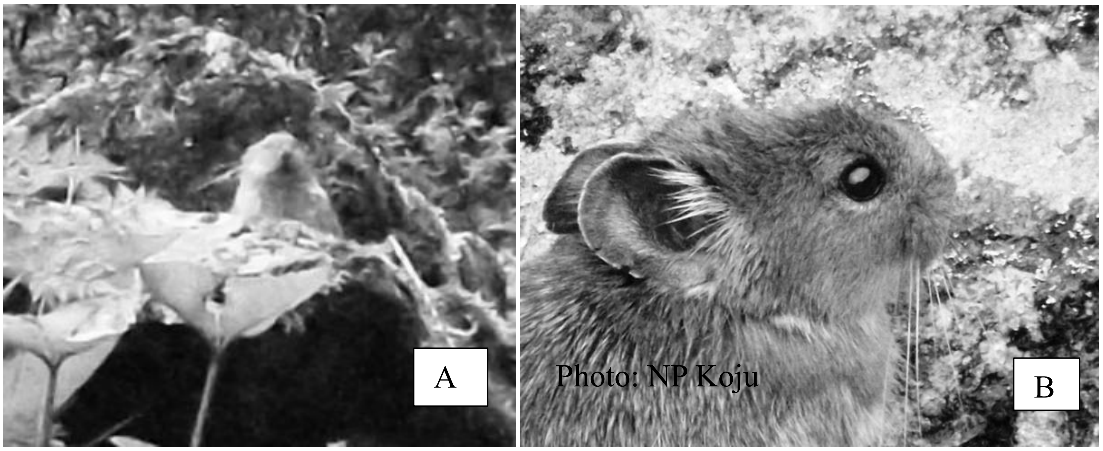


Figure 31: A. Pika making call B. Pika with tear ear sign of fight

4.3.9 Special behaviours

Except eight focused behaviour; grooming, musing, feeding, foraging, chasing, calling, inside burrow and galloping others taken were regarded as special behaviour. Reproductive behaviour, drinking of water, licking of rock or soil, parental care, stealing food from people's farmland and houses and discharging pellets are included in special behaviour. These behaviours were not commonly observed and were observed in very less frequency or just single time.

4.3.9.1 Mating behaviour

Observation of mounting in pika reported rarely. During this study period, they were observed mounting for two times. First observation was in March 2012, at Thadepati. There Royle's pikas were observed chasing each other for 2-3 minutes. During chasing they used multiple burrows entering and existing, and finally male (which mount on) observed mounting for 3-5 seconds. Chasing was followed by calling of short call of 'chi chi'. After mounting they were separated and enter different burrows (Fig 32). The chasing observed in this situation was different from other chasing behaviour. Second observation was in April 2012 in Ithang area. It was *O. macrotis*. In Ithang, female pika was notice musing for long time but male was not noticed there. Long and sharp call was heard around the musing pika (may be the calling of male). The musing female was chased and started chasing each other; they chased entering and existing different burrows. Copulation was observed near the musing stone for 3-5 seconds. Both of the mating was observed afternoon before sunset.

Figure 32: Post copulatory sitting (Musing?) of two pikas in LNP.

4.3.9.2 Parental care

Parental care in pika is rarely reported too. In this research, this behaviour was observed for a time in rainy season (July 2012) at Thadepati. Two Juveniles were observed traveling with two adult pikas (possible parents).

Figure 33: Adult pika monitoring in Ithang, Langtang.

They came out from the same burrow; the adults climbed on the big rock near burrow. One of them made call (possible male!) and sat on stone like musing. Two Juveniles and another adult (possible female!) were feeding green grass together. During feeding, they enter burrow and come out together in very short period. The adult musing on rock made several long calls during this period but the significance of calling was unknown (Fig 33). It was social behaviour showing parental care in the pika. The adults look after the juveniles while feeding but feeding by adult to juveniles and milking juvenile was not observed.

4.3.9.3 Pollution and pika

Gosainkunda and its associated lakes in Langtang National Park are famous high altitude lakes. It is one of the Ramsar listed wetland. Every year thousands of pilgrims both Hindu and Buddhist visit there for their holy cause and belief. Annually thousands of tourists visit Langtang National Park too. There are several small hotels in different elevation of the national park. Around Gosainkunda, lake premises there were five hotels too. In the period of festival (Gosainkunda Mela), there were hundreds of temporary huts in this route. This movement of people is increasing anthropogenic pollution in Langtang National Park and pika habitat. Pollutants were especially plastic, paper, cloths, bottles, used batteries and other non-degradable wastes (Fig 34).

Figure 34: Pollution in pika habitat, LNP.

Study on pollutants was only qualitative measurement in this research. The information on pollution and pollutants were recorded only in course of behaviour observation as it is related with behaviour of pika. We do not study detail about amount and types of pollution. In different field works pollutant were observed in pika habitat especially in Gosainkunda area. Plastics and cloths were deposited in between rock gap and the burrow used by pika. In July 2011, some pikas in Gosainkunda were making sound after they were being disturbed by plastic for entering and exit burrow. A pika was observed carrying piece of plastic sac too. It tore the sac and run to about five meters with mouthful of polymer then entered the burrow. It returned from burrow after 30-35 seconds without polymer to the same place. It continued this behaviour for three times on that day. Collecting or transferring plastics and nonfood substance is unusual behaviour of pika. In July, pika population density was 18.62 per ha but pika around Gosainkunda lake premises were not seen from March 2012.

4.3.9.4 Discharging pellets

Pika is strictly herbivorous animal. It feeds on different green plants at different elevation. It discharged pellets as fecal matters. The number of pellets was different in adult and juveniles and their size found varying from 1.8 mm to 2.1 mm. Pikas deposit two kinds of fecal droppings: hard brown round pellets and soft caecal pellets. The soft caecal pellets greenish-black, shiny with more moisture, and larger. The pellet numbers vary from 7 to 12 in single discharge. There was not any difference in the size and colour of pellets of both species. Hard brown pellets were observed mainly in winter and caecal pellets were observed in summer and rainy season. They discharge pellets near the opening of burrow. Some very fresh pellets were seen on leaflets of plants around the burrow too (Fig 35).

Pellets were discharged at same place by individual pika for long time. Therefore, the mouth of burrow and its surrounding had piles of pellets. Old pellets were dry and grayish white in colour. Some of them were found with fungus and degraded to form humus. Pikas were observed scratching on rocks and digging on soft soil while defecation. Defecation after this behaviour has less number of pellets than in normal. This resembles possible territorial marking by scratching and defecation. Pika is coprophagous animal; they feed on their own caecal pellets. Caecal pellets were easily observed in summer but are often not seen in winter. Pikas in different elevation were observed feeding their pellets near their burrow in winter. In one event, pikas were observed feeding on dry cow-dung. The reason for cow-dung utilization is still unknown; it may be consuming minerals or remaining nutrients from it as they do for their own.

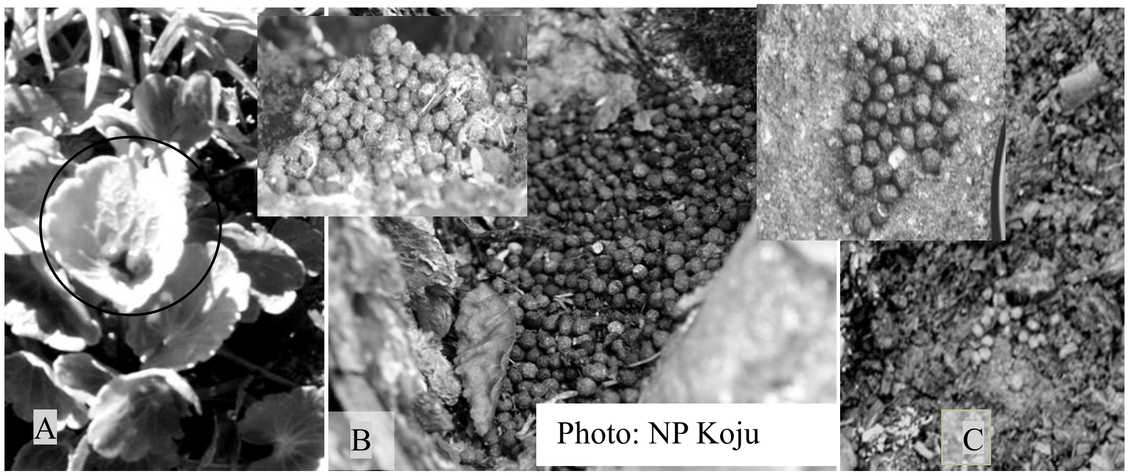


Figure 35: A.Caecal pellets B. Pellets near mouth of Burrow C. hard pellets.

4.3.9.5 Drinking water and licking rock/soil (Geophagy)

Pika feed on green vegetation. Delicate and green plants will supply the major source of water to them. During the total field work (459 hours), the pikas were observed licking water just for two times.

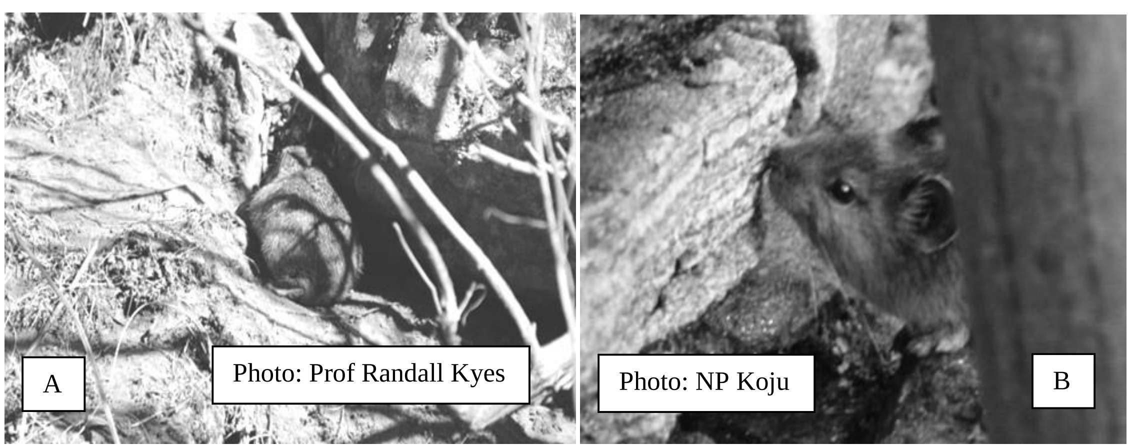


Figure 36: A. *O. roylei* licking soil from ground B. *O. roylei* licking water from stone after rain, LNP

Both of the incidents were observed in Laurebina in one season (2012 July). After fresh rain, the Royle's pika came on big rock for musing. After short musing, it licked the water on the surface of stone. It licked for 5-6 times by using tongue and resumed in musing (Fig 36). Pikas (both species) were observed very often-licking rock and soil during January, March and April. This is dry season with very dry plants available. Pika might have licked rocks and soils for fulfillment of required minerals.

4.4 Feeding ecology and nutrition

Feeding behaviour was recorded during observation of pikas along with other behaviour in three different habitats. Focal scan sampling was used to observe feeding behaviour. During observation of feeding behaviour, the plant species consumed by pika was noted along with habitat too. To explore the diversity of vegetation in pika habitat forty quadrats (1m x 1m) were plotted in four different habitats of Langtang National Park. For nutritional analysis and plant diversity, habitats were categorized into forest and its edge, subalpine with broken rocks, alpine area and Gosainkunda lake premises. Even Gosainkunda lake area itself is in alpine characteristics; therefore, it was studied separately as there was different plant species with other alpine area and pika were observed consuming all types of ground vegetation of Gosainkunda area. Plants specimens inside the area of quadrats were collected from different habitat for scientific identification. They were identified with the help of plant taxonomist in National Herbarium and Laboratory, Godawari, Nepal (Table 9-11).

Figure 37: A. *O. roylei* feeding without picking B. *O. roylei* cut leaf and moving for feeding, LNP.

Pika usually feed plants in two ways: instant feeding and transferring the feeding materials to construct hay pile for winter storage. In instant feeding, pika feed again in two ways; if the plant is small and its leaf or other consuming parts were small and delicate, it feeds at the plant uprooted site (Fig 37), specially plants like *Sterallia alsine, Fragaria nubicola, Bistorta affinis,* Moss, lichens, *Poa* species, *Gramineae* species, *Potentilla* species, *Fragaria* species, *Juncus thomosnii* and others.

They were consumed directly whole plant without tearing its parts. Plants which are larger in size, with broad and large leaf; pika tears the leaf or cut the petiole and carry it to a few distance near big rock or open ground and feed there. After consumption carried plant parts, pika again repeat cutting the large part of plant similar way and move to same place for feeding (Fig 38).

Figure 38: *O. roylei* carrying plants to construct hay pile for winter storage, LNP.

Especially, plants like *Ligularia ampllexicaulis, Apiaceae, Asplenium* species, *Argemone* species, *Euphorbia* species, fern, etc., were consumed in this pattern. *Rumex* species, *Potentilla* species and *Primula* species were also cut and carried a distance before feeding.

Another way of feeding was storing food for winter hay pile (Fig 38). Both species of Pikas in Langtang were not active in storing hay pile. Only seven hay piles were observed during winter season with dry vegetation of *Juncus thomosnii, Fragaria* species, *Argemone* species, *Ligularia ampllexicaulis, Artemisia vulgare, Poa* species, *Gramineae* species, and some very dry plant species that were unidentified.

In summer, Royle's pika at forest and its edge area were not observed carrying forage for winter hay pile. During field works in rainy and summer season this behaviour were observed 12 times; three in Thadepati, six in Phedi, one in Laurebina area and two in

Langtang valley. Between them only two incidents belonged to *O. macrotis* in Phedi, while rests of all were shown by *O. roylei*. Fresh hay pile contained majorly *Fragaria* species, *Potentilla* species, *Primula* species, *Ligularia ampllexicaulis, Gramineae* species, *Juncus* species and *Poa* species (Fig 39). These all plants were highest frequency consumed plants species in their respective habitat.

Figure 39: A. Fresh hay pile in summer and rainy B. Dry hay pile in winter in LNP.

The biting (chewing too) of food by pika was recorded in video and replaying the video biting rate was counted. The biting rate was 140.06 ± 3.52 per minute (df= 15, SD= 13.64). Pika bites the forage very fast and can continue biting the large forage without holding it. While chewing large sized food/forage like *Ligularia ampllexicaulis*, *Rumex nepalensis, Argemone* species, *Apiaceae* species, *Mecanopsis paniculata*, *Plantago brachyphylla* and *Euphorbia* species: they manipulated the plants and its parts left and right of its mouth and some parts of food were dropped. Feeding again on those, dropped plant parts were not observed.

4.4.1 Diversity of ground vegetation in pika habitat

In the study area, species recorded total sixty-five plants in quadrats as ground vegetation. Among them fifty eight species were consumed in all habitats; *Gallium verum* (4) was the least consumed plant which was followed by *Danthonia cachemiriana* (6), *Argemone* species (8) *Artemisia vulgare* (8) and *Gramineae* species was the highest (411) frequency consumed plants among all forage plants species (N= 5,829). Seven of them (*Corydalis juncea, Hakelia uncinatam, Leontopodium jacotianum, Rhododendron setusum, Rhododendron anthropogan,* Shindure and mushroom) were not observed consumed by pika during field study. Fifteen species of plants were consumed in all four habitats, twenty-three species of plants were consumed by pikas in three habitats, four species of plants (*Alliaria* species, *Anaphalis triplinervis, Rumex nepalensis, and* Fern species) were consumed in two habitats and sixteen species of forage plants and their parts were consumed only in one habitat (Table 10).

Table 10: List of plants species and their parts consumed by pika in different habitat.

Habitats	Plants species
Single habitat	*Argemone* species, *Artemisia vulgare, Botrichium* species *Carex setigera, Danthonia cachemiriana, Gallium verum, Moehringia* species, *Oxygraphis polypetala, Pedicularis megalantha, Rosaceae* species, *Salix* species, *Selinum tenuifolium, Tanacetum parthene, Viola biflora, Valeriana* species, and Lichens (N=16).
Two habitats	*Alliaria* species, *Anaphalis triplinervis, Rumex nepalensis,* Fern (N=4)
Three habitats	*Anaphalis intermedia, Anaphalis royleana, Asplenium* spp, *Caltha polustris, Euphorbia* species, *Fragaria nubicola, Jurinea dolomiaea, Kobresia* species, *Mecanopsis paniculata, Plantago brachyphylla, Poa* species, *Polygonum* species, *Potentilla afestiva, Potentilla fruticosa, Potentilla fulgens, Primula* species, *Prunella vulgaris, Ranunculus* spp, *Saussurea nepalensis, Sibbaldia cuneata, Sibbaldia micropetala, Thallicrum alpinum, Trachydium roylei,* and *Voila walliciana*(N=23).
All habitats	*Apiaceae* species, *Bistorta affinis, Bistorta microphylla, Bistorta vaccinifolia, Fragaria daltoniana, Geranium nakaoanum, Geumelatum* species, *Gramineae* species, *Juncus thomosnii, Ligularia ampllexicaulis,Potentilla microphylla, Potentilla peduncularis, Stellaria alsine,Taraxacum officinale* and Moss (N=15).
Not consumed	*Corydalis juncea, Hakelia uncinatam, Leontopodium jacotianum, Rhododendron setusum, R. anthropogan,* Shindure and mushroom

4.4.1.1 Forest and its edge area

In forest and its edge area forty-six of ground vegetation were recorded. Among them thirty, three were observed consumed by pika. Leaf of all plants, root of *Artemisia vulgare*, and flowers of *Bistorta microphylla, Fragaria daltoniana, Fragaria nubicola,* fruits of *Fragaria* species were consumed in that habitat. Moss on the rocks and tree trunk or barks of *Rhododendron* species were consumed for few times too. Pikas in this habitat were noticed short climbing to twigs (bending) and branches of tree and shrubs to feed moss on them. Among total feeding behaviour, pikas were observed feeding 390 minutes in this habitat. Among them 303 minutes for adult and 87 minutes for juvenile *O. roylei* species. *O. macrotis* were not observed in this habitat. Total 71.73% (33 species) of plants species (ground vegetation) were consumed by pika (Table 11).

Table 11: List of plants species in forest and its edge area with consumption frequency by pika in LNP.

		Frequency of consumption		
List of consumed species	**Parts consumed**	**Adult**	**Juvenile**	**Total**
1. *Alliaria* species	Leaf	5	0	5
2. *Apiaceae* species	Leaf and stem	6	0	6
3. *Argemone* species	Leaf	7	1	8
4. *Artemisia vulgare*	Leaf and root	5	3	8
5. *Asplenium* species	Leaf	11	1	12
6. *Bistorta affinis*	Leaf	5	1	6
7. *Bistorta microphylla*	Leaf and flower	29	2	31
8. *Bistorta vaccinifolia*	Leaf and flower	7	2	9
9. *Carex setigera*	Leaf	12	1	13
10. *Danthonia cachemiriana*	Leaf	4	2	6
11. *Fragaria daltoniana*	Leaf and flower	12	3	15
12. *Fragaria nubicola*	Leaf and flower	14	2	16
13. *Gallium verum*	Leaf	3	1	4
14. *Geranium nakaoanum*	Leaf	18	4	22
15. *Geumelatum* species	Leaf	8	2	10
16. *Gramineae* species	Leaf and stem	27	9	36
17. *Juncus thomosnii*	Leaf	6	3	9
18. *Ligularia ampllexicaulis*	Leaf	7	3	10
19. *Moehringia* species	Leaf	7	0	7
20. Moss	Plant scratch	6	2	8
21. *Poa* species	Leaf	17	5	22
22. *Polygonum* species	Leaf, petiole	8	3	11
23. *Potentilla microphylla*	Leaf	18	10	28
24. *Potentilla peduncularis*	Leaf	3	1	4
25. *Prunella vulgaris*	Leaf	3	1	4
26. *Rumex nepalensis*	Leaf	17	7	24
27. *Sterallia alsine*	Leaf	12	8	20
28. *Tanacetum parthene*	Leaf	5	2	7
29. *Taraxacum officinale*	Leaf	7	1	8
30. *Thallicrum alpinum*	Leaf	5	2	7

31. *Trachydium roylei*	Leaf	2	2	4
32. *Valeriana* species	Leaf	4	2	6
33. *Voila walliciana*	Leaf	3	1	4
	Total	**303**	**87**	**390**

During observation period *Gramineae* species was consumed for the most frequency (11.65%) which was followed by *Bistorta microphylla* (7.94%), *Potentilla microphylla* (7.12%), *Rumex nepalensis* (6.15%), *and Geranium nakaoanum* (5.64%), *Poa* species (5.64%), *Sterallia alsine* (5.12%) *and Fragaria nubicola* (4.15%).

Plant species not consumed in forest and its edge area

The thirteen plants species (28.27%) recorded by the quadrats were not consumed in this habitat. They were *Selinum tenuifolium, Anemone* species, *Hakelia uncinatam, Leontopodium jacotianum, Pedicularis* species, *Ranunculus* species, *Rhododendron setusum, Selinum tenuifolium,* Sindhure, fern I, fern II, lichens and mushroom in this habitat.

4.4.1.2 Subalpine with broken rock area

Subalpine with broken rocks had 52 species of plants as ground vegetation. Among them 46 species were consumed by pika. Leaf of all plant species, flowers of *Bistorta affinis, Bistorta microphylla, Bistorta vaccinifolia, Fragaria daltoniana, Fragaria nubicola, Primula* species, *Prunella vulgaris, Ranunculus* species and fruits of *Fragaria* species were consumed by pika. Some plants like *Apiaceae* species, *Asplenium* species, *Polygonum* species and all *Potentilla* species's stem or petiole were consumed too (Table 12). Feeding was observed for total 1551 minutes in this habitat. Behaviour of adult *O. roylei* for 846 minutes, juvenile *O. roylei* for 225 minutes, adult *O. macrotis* for 438 minutes and its juvenile for 42 minutes were recorded.

Total 88.46% of plants (forty species) were consumed in this habitat. During observation period pika were found feeding *Gramineae* species the most (6.45%), it was followed by *Fragaria nubicola* (5.67%), *Rumex nepalensis* (5.6%) and *Voila walliciana* (5.29%). All the forage plants recorded in quadrats at subalpine area were also found in other habitats.

Table 12: List of plants species in subalpine area with their consumption frequency by pika in LNP.

Consumed plant species	Parts consumed	Frequency of consumption by pika				
		AOR	JOR	AOM	JOM	Total
1. *Alliaria* species	Leaf	23	5	12	2	42
2. *Anaphalis intermedia*	Leaf	5	1	7	3	16
3. *Anaphalis royleana*	Leaf	3	2	3	1	9
4. *Anaphalis triplinervis*	Leaf	9	2	1	1	13
5. *Apiaceae* species	Leaf and stem	15	9	15	3	42
6. *Asplenium* species	Leaf and stem	4	2	1	1	8
7. *Bistorta affinis*	Leaf and flower	3	1	3	1	8
8. *Bistorta microphylla*	Leaf and flower	17	4	12	0	33
9. *Bistorta vaccinifolia*	Leaf and flower	4	1	2	1	8
10. *Caltha polustris*	Leaf	8		13	0	21
11. *Euphorbia* species	Leaf	4	2	5	1	12
12. *Fern* species	Leaf	15	2	14	0	31
13. *Fragaria daltoniana*	Leaf and flower	28	2	23	0	53
14. *Fragaria nubicola*	Leaf and flower	49	12	25	2	88
15. *Geranium nakaoanum*	Leaf	35	17	30	0	82
16. *Geumelatum* species	Leaf	4	3	5	1	13
17. *Gramineae* species	Leaf	54	15	28	3	100
18. *Juncus thomosnii*	Leaf	53	9	18	0	80
19. *Jurinea dolomiaea*	Leaf	14	1	2	1	18
20. *Kobresia* species	Leaf	2	3	6	1	12
21. *Ligularia ampllexicaulis*	Leaf	21	7	6	0	34
22. *Mecanopsis paniculata*	Leaf	11	0	3	0	14
23. Moss	Whole part	14	5	7	0	26
24. *Plantago brachyphylla*	Leaf	11	2	21	1	35
25. *Poa* species	Leaf	35	5	13	0	53
26. *Polygonum* species	Leaf and petiole	21	1	8	0	30
27. *Potentilla afestiva*	Leaf and petiole	13	4	7	2	26
28. *Potentilla afruticosa*	Leaf and petiole	9	1	0	1	11
29. *Potentilla atrosanguinea*	Leaf and petiole	5	4	5	2	16
30. *Potentilla fulgens*	Leaf and petiole	3	4	1	0	8
31. *Potentilla microphylla*	Leaf and petiole	5	2	5	1	13
32. *Potentilla peduncularis*	Leaf	33	5	9	0	47
33. *Potentilla peduncularis*	Leaf	14	3	5	1	23
34. *Potentilla* species	Leaf	34	6	12	0	52
35. *Primula* species	Leaf and flower	47	13	9	1	70
36. *Prunella vulgaris*	Leaf and flower	3	1	9	5	18
37. *Ranunculus* species	Leaf and flower	41	8	11	0	60

38. *Rumex nepalensis*	Leaf		47	17	22	1	87
39. *Saussurea nepalensis*	Leaf		15	2	1	1	19
40. *Sibbaldia cuneata*	Leaf		13	2	5	1	21
41. *Sibbaldia micropetala*	Leaf		4	4	6	2	16
42. *Sterallia alsine*	Leaf		23	11	13	0	47
43. *Taraxacum officinale*	Leaf		7	1	2	0	10
44. *Thallicrum alpinum*	Leaf		23	2	9	0	34
45. *Trachydium roylei*	Leaf		3	1	5	1	10
46. *Voila walliciana*	Leaf		42	21	19	0	82
		Total	**846**	**225**	**438**	**42**	**1551**

Note: In table AOR = Adult *Ochotona roylei*, JOR = Juvenile *O. roylei*,
AOM = Adult *O. macrotis* and JOM = juvenile *O. macrotis*.

Plant species not consumed in subalpine with broken rock area

There were six (11.64%) plant species recorded in the quadrats but not consumed by pika in this habitat. They were *Anemone* species, *Hakelia uncinata*, *Leontopodium jacotianum*, *Moehringia* species, *Rhododendron setusum* and Sindhure (local name). Among those plants species all plants species and their parts were never observed consumed by in except *Moehringia* species. This plant was consumed by Royle's pika in forest and its edge habitat.

4.4.1.3 Alpine area

In alpine talus area, there were forty-seven plant species as ground vegetation. Among them forty plant species were consumed by pika in this area. Leaf of all forty plants, leaf and flower of *Bistorta microphylla, Bistorta vaccinifolia, Caltha polustris, Fragaria daltoniana, Oxygraphis polypetala*, *Primula* species, *Ranunculus* species and *Rosaceae species* were consumed while whole parts of *Potentilla peduncularis,* moss and lichens were utilized by pika. Total feeding was observed for 2488 minutes among them adult *O. roylei* for 526 minutes, its juvenile for 512 minutes, adult *O. macrotis* for 1306 minutes and its juvenile for 154 minutes (Table 13).

Total 85.10% of plants species in this habitat were consumed. During observation period, *Apiaceae* was consumed the most (6.99%). *Apiaceae* species is carrot like leafed plant found in Thadepati and Phedi area, Pika of Phedi (subalpine area) was observed consuming the most frequency by both species of pika. It was tall grass with long petiole and compound leaf associated in bush. Local people and herders believed that this plant is poisonous for their livestock especially goats and sheep that cause ulcer in their gastro-intestinal tract.

Table 13: List of plants species in alpine and talus area and consumption frequency by pika in LNP.

Consumed plant species	Parts consumed	Frequency of consumption by pika				
		AOR	JOR	AOM	JOM	Total
1. *Apiaceae* species	Leaf and stem	27	23	102	22	174
2. *Anaphalis intermedia*	Leaf and stem	12	5	6	2	25
3. *Anaphalis royleana*	Leaf and stem	2	4	1	1	8
4. *Bistorta affinis*	Leaf and stem	11	2	3	2	18
5. *Bistorta microphylla*	Leaf and flower	12	14	52	0	78
6. *Bistorta vaccinifolia*	Leaf and flower	4	12	2	3	21
7. *Botrichium* species	Leaf	11	9	45	2	67
8. *Caltha polustris*	Leaf and flower	5	12	34	1	52
9. *Euphorbia* species.	Leaf	2	1	3	1	7
10. *Fragaria daltoniana*	Leaf, flower	25	51	82	14	172
11. *Geranium nakaoanum*	Leaf	12	32	42	0	86
12. *Geumelatum* species	Leaf	1	3	4	0	8
13. *Gramineae* species	Leaf and stem	38	41	67	11	157
14. *Juncus thomosnii*	Leaf	25	12	63	0	100
15. *Jurinea dolomiaea*	Leaf	5	2	3	2	12
16. *Kobresia* species	Leaf	6	2	4	1	13
17. Lichens	Whole part	5	9	31	0	45
18. *Ligularia amplllexicaulis*	Leaf	23	31	77	8	139
19. *Mecanopsis paniculata*	Leaf	3	0	7	0	10
20. Moss	Whole part	13	23	44	0	80
21. *Oxygraphis polypetala*	Leaf and flower	3	2	9	1	15
22. *Pedicularis megalantha*	Leaf	28	26	94	12	160
23. *Plantago brachyphylla*	Leaf	5	1	2	1	9
24. *Potentilla afestiva*	Leaf	2	2	3	2	9
25. *Potentilla afruticosa*	Leaf	5	1	3	1	10
26. *P. atrosanguinea*	Leaf	12	2	4	1	19
27. *Potentilla flugens*	Leaf	18	12	6	3	39
28. *Potentilla microphylla*	Leaf	12	4	14	1	31
29. *Potentilla peduncularis*	Whole plant	34	21	89	2	146
30. *Primula* species	Leaf and flower	12	6	17	2	37

31. *Ranunculus* species	Leaf and flower	29	18	74	13	134
32. *Rosaceae* species	Leaf and flower	18	22	81	12	133
33. *Salix* species	Leaf	13	31	56	9	109
34. *Saussurea nepalensis*	Leaf	23	25	43	0	91
35. *Selinum tenuifolium*	Leaf	6	1	7	1	15
36. *Sibbaldia cuneata*	Leaf	17	13	23	0	53
37. *Sibbaldia micropetala*	Leaf	2	0	22	1	25
38. *Stellaria alsine*	Leaf	5	5	16	4	30
39. *Taraxacum officinale*	Leaf	15	23	59	14	111
40. *Viola biflora*	Leaf	25	9	12	4	50
	Total	**526**	**512**	**1306**	**154**	**2498**

Note: In table AOR = Adult *Ochotona roylei*, JOR = Juvenile *O. roylei*, AOM = Adult *O. macrotis* and JOM = juvenile *O. macrotis*.

Seven plant species (17.5%) in the alpine were recorded in quadrats but not seen consumed by pika. They were *Anemone* species, *Apiaceae* species, *Caltha polustris, Corydalis juncea, Euphorbia* species, *Rhododendron anthropogan* and Fern.

4.4.1.4 Gosainkunda lake premises

Gosainkunda Lake is at elevation of 4300 masl, it is in alpine talus habitat. During field visit of July 2011 pika were observed consuming all the ground vegetation species around the Lake premises. In this area, total feeding behaviour was observed for 1400 minutes. It was 668 minutes for *O. roylei*, 108 for its juvenile, 498 minutes for adult *O. macrotis* and 126 minutes for its juvenile. In Gosainkunda Lake premises, it was recorded 27 species of ground vegetation and all of them were observed to consume by pika. As in other habitats, pikas in Gosainkunda fed whole parts of mosses and lichens (Table 14).

Table 14: List of plants species in Gosainkunda Lake premises and consumption frequency of pikas.

Consumed plant species	Parts consumed	Frequency of consumption				
		AOR	**JOR**	**AOM**	**JOM**	**Total**
1. *Anaphalis triplinervis*	Leaf	25	0	12	1	38
2. *Anemone* species	Leaf	12	4	22	1	39
3. *Bistorta affinis*	Leaf and flower	9	0	5	2	16
4. *Bistorta microphylla*	Leaf and flower	11	0	23	1	35
5. *Botrichium* species	Leaf	43	0	45	3	91
6. *Caltha polustris*	Leaf	52	0	43	1	96

7. Fern	Leaf	19	3	11	1	34
8. *Fragaria daltoniana*	Leaf, flower	25	12	13	0	50
9. *Geranium nakaoanum*	Leaf	17	0	6	5	28
10. *Gramineae* species	Leaf and stem	81	8	23	12	124
11. *Juncus thomosnii*	Leaf	77	9	35	21	142
12. *Jurinea dolomiaea*	Leaf	12	4	11	5	32
13. *Kobresia* species	Leaf	3	1	12	1	17
14. *Leontopodium jacotianum*	Leaf	21	1	15	2	39
15. Lichen	Whole parts	16	0	11	5	32
16. *Mecanopsis paniculata*	Leaf	5	1	8	1	15
17. Moss	Whole parts	13	2	11	4	30
18. *Oxygraphis polypetala*	Leaf and flower	7	2	3	1	13
19. *Potentilla flugens*	Leaf	41	6	31	6	84
20. *Potentilla peduncularis*	Leaf	29	0	23	7	59
21. *Primula* species	Leaf	31	11	22	1	65
22. *Ranunculus* species	Leaf	45	20	29	16	110
23. *Rosaceae* species	Leaf	23	13	18	9	63
24. *Salix* species	Leaf	14	3	13	9	39
25. *Saussurea nepalensis*	Leaf	2	1	7	1	11
26. *Selinum tenuifolium*	Leaf	21	2	33	6	62
27. *Voila walliciana*	Leaf	14	5	13	4	36
	Total	**668**	**108**	**498**	**126**	**1400**

Note: In table AOR = Adult *Ochotona roylei*, JOR = Juvenile *O. roylei*, AOM = Adult *O. macrotis* and JOM = juvenile *O. macrotis*.

During observation period, the most consumed plant was *Juncus thomosnii* (10.14%). Caltha palustris (6.85%), Botrichium (6.50%) and the least consumed was Saussurea nepalensis followed it. However, pikas were not observed in Gosainkunda Lake premises in field scurvies since March 2012.

4.5 Nutrients in consumed forage

4.5.1 Nutrients in plants of forest and its edge area

In forest and its edge, area thirty-three plant species were consumed out of forty-six species recorded. The six plant species were most consumed (in frequency): *Potentilla microphylla* (7.12%), *Gramineae* species (11.65%), *Rumex nepalensis* (6.15%), *Poa* species (5.64%), *Geranium nakaoanum* (5.64%) and *Bistorta microphylla* (7.94%). The value of total ash in these plants were 10.77 %, 5.66%, 22.42%, 25.04%, 19.00% and 12.44% respectively (Table 15).

Table 15: Nutritional value of the six most consumed plant species in forest and its edge area, LNP

Nutrients	***Bistorta* species**	***Geranium* species**	***Gramineae* species**	***Poa* species**	***Potentilla* species**	***Rumex nepalensis***
T. Ash	12.44	19	5.66	25.04	10.77	22.42
OM	87.56	81	94.34	74.96	89.23	77.58
NDF	38.36	50.72	78.39	50.75	48.75	58.1
ADF	29.83	45.77	64.58	45.41	44.56	57.83
ADL	22.66	15.99	49.41	28.14	16.11	36.4
HC	8.53	4.96	13.81	5.35	4.19	0.27
C	7.17	29.78	15.16	17.27	28.45	21.43
Pr.	16.9	4.3	12.71	2.7	13.67	12.99
K	1.2	5	2	1.1	6.4	5.8
P	54.2	2.91	1	1.86	2.77	1.86
Ca	3.9	2.4	5.7	4.2	8.7	11
MC	87.14	82.32	83.96	82.08	81.24	88.49
RFV index	1.43111	0.90573	0.33036	0.9048	0.97158	0.69871
TDN (%)	79.613	71.3679	52.917	71.348	72.6812	66.4471
NEc index	0.64564	0.3923	0.09321	0.3980	0.4115	0.20052

(Note: T. ash = Total Ash, OM = Organic matter, T. Ash = Total Ash, K = Potassium, P = Phosphorus and Ca = calcium and MC = moisture contain, RFV index= Relative feed value index, TDN = Total digestible nutrient and NEc = Net energy consumed).

All the plants consumed by pika contained high moisture. Moisture content was the value difference between wet weight of the sample and its dry weight. The highest moisture contain was in *Rumex nepalensis* (88.49%) and *Bistorta* species (87.14%) in this area, and the least among the six plants species was in *Poa* species (82.08%), *Geranium* species (82.32%) and *Potentilla microphylla* (81.24%).

The value of NDF was highest in *Gramineae* species (78.39%) which was followed by *Rumex nepalensis* (58.1%). Rest of other have the value of NDF less than 50% and *Bistorta* *microphylla* had the lowest value (38.36%). The value of ADL was highest in *Gramineae* species (49.41%), which was followed by *Rumex nepalensis* (36.4%), *Poa* species (28.14%), *Bistorta microphylla* (22.66%), *Potentilla microphylla (*16.11) and the lowest *Geranium nakaoanum* (15.99%). Acid Detergent Lignin was the highest in *Gramineae* species (64.58%), and the least in *Bistorta microphylla* (Fig 40).

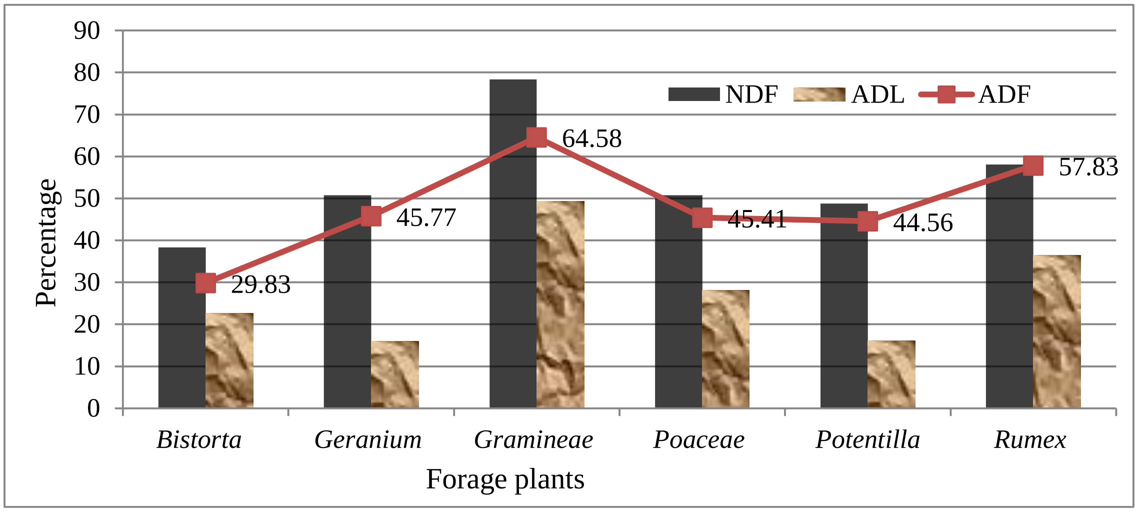


Figure 40: Comparison between ADF, NDF and ADL of major plants of forest area, LNP.

The total organic matter was highest in *Gramineae* species (94.34%), and the lowest in *Poa* spp (74.96%). The ratio of hemi-celluloses and cellulose was 8.53:7.17 in *Bistorta microphylla*, 4.96:29.78 (*Geranium nakaoanum*), 4.19:28.45 in *Gramineae* species, 5.35:17.27 (*Poa* species), 13.81:15.16 (*Potentilla microphylla)*, and 0.27:21.43 (*Rumex nepalensis*). *Bistorta microphylla* had the most protein (16.9%) while *Poa* species had the least protein (2.7%) (Fig 41)

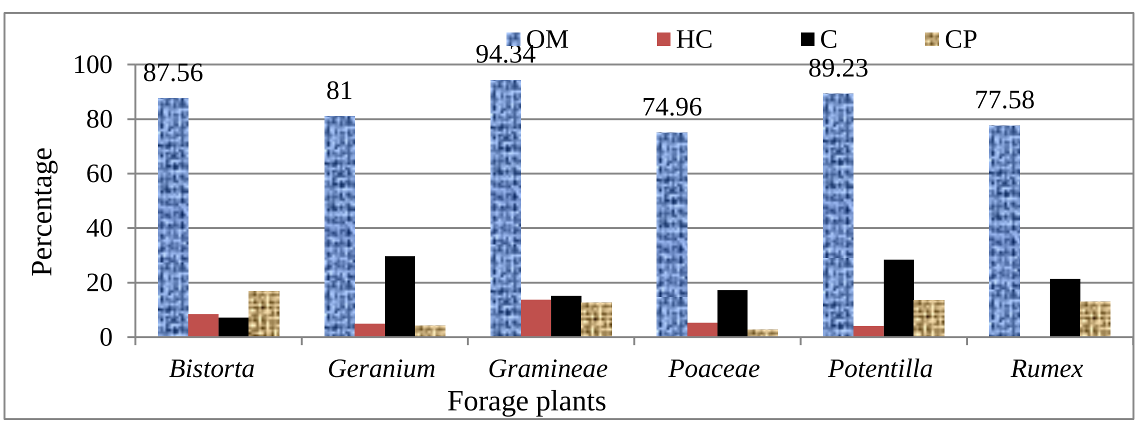


Figure 41: Level of major nutrients in major plants of forest and its edge area, LNP.

The amount of phosphorus in six consumed plant was highest in *Bistorta microphylla* (5.42 mg/g), and the least in *Gramineae* species (1mg/g). The value of calcium and potassium was highest in *Rumex nepalensis;* calcium (11mg/g) and Potassium (5.8mg/g). It was followed by *Potentilla microphylla* in which calcium was 8.7 mg/g and potassium was 6.4 mg/g. *Bistorta microphylla* had the least potassium (1.2mg/g) and *Geranium nakaoanum* had the least Ca (2.4mg/g) among six consumed species in forest and its edge (Fig 42).

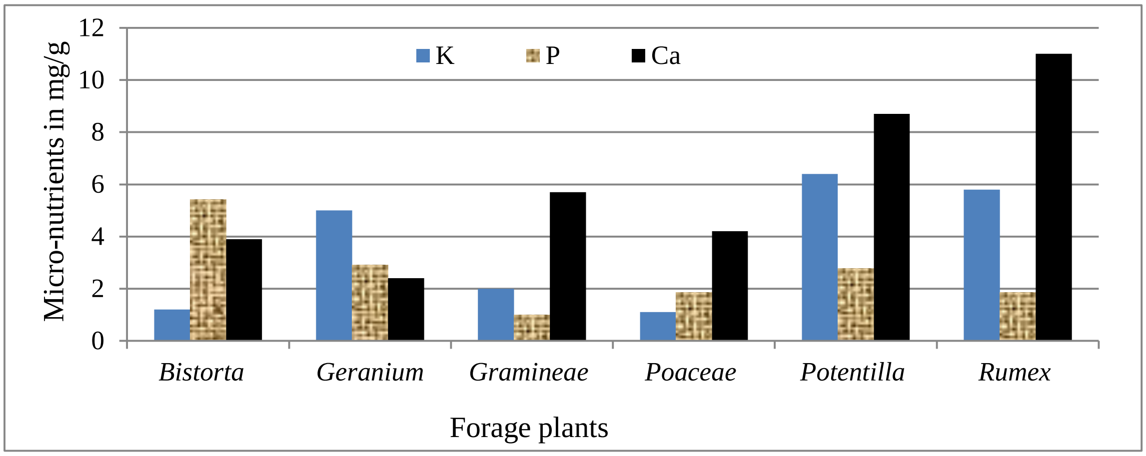


Figure 42: Level of micronutrients in major plants of forest and its edge area, LNP.

Bistorta microphylla in this habitat had the most relative feed value index (1.43), total digestible nutrient (TDN%= 79.61%) and net energy consumed index (0.64). This was the second most consumed (7.94%) plant in this habitat. *Potentilla microphylla* had RFV index 0.97 with TDN 72.68% and NEc 0.41. *Potentilla microphylla* was the third most consumed (7.12%) plant. The *Gramineae* species consumed for highest frequency but had the lowest RFV index (0.33), TDN value (52.91%) and the least NEc index (0.093). *Poa* species and *Geranium nakaoanum* had equal RFV index, TDN % and NEc index which are 0.90, 71.3 and 0.39 respectively and the interesting data is, they were consumed in equal frequency too (Table 9 and Table 13).

4.5.2 Nutrients in subalpine with broken rocks area

In subalpine area with broken rocks forty nine plant species consumed by pika and following were six the most consumed plant species (in frequency): *Fragaria nubicola*, *Rumex nepalensis*, *Viola wallichiana*, *Juncus thomosnii*, *Gramineae* species *and Geranium* species. The value of total ash was highest in *Geranium* species (17.33%) and the least in

8.22% in *Gramineae* species. All the plants consumed by pika contained more that 72% moisture in this area. The highest moisture was in *Rumex nepalensis* (90.72%) which is followed *Gramineae* species (88.45%), *Fragaria nubicola* (88.31%), and the least moisture content among the six plants species was in *Juncus thomosnii* (72.73%) (Table 16).

Table 16: Nutritional value of the six most consumed plants subalpine and broken rock area

Nutrient	***Fragaria nubicola***	***Geranium* species**	***Graminea e* species**	***Juncus thomosnii***	***Rumex nepalensis***	***Viola***
T. Ash	10.82	17.33	8.22	4.86	11.62	13.29
OM	89.18	82.67	91.78	95.14	88.38	86.71
NDF	44.38	44.64	86.96	81.01	62.19	44.85
ADF	38.49	39.63	56.15	53.33	52.19	35.88
ADL	14.81	24.7	14.46	11.37	27.41	23.97
HC	5.9	5.01	30.8	27.68	10.01	8.98
C	23.68	14.93	41.69	41.95	24.78	11.91
CP	10.68	5.37	15.41	11.03	24.62	13.19
K	2	3.5	2.1	2	10.5	24
P	0.45	1.22	0.72	0.87	1.34	0.69
Ca	4.3	7.1	6.2	2.3	5.8	2.5
MC	88.31	80.01	88.45	72.73	90.72	79.18
RFV index	1.13	1.1279	0.22633	0.29618	0.60511	1.11922
TDN	75.59	75.4251	47.1977	51.1663	63.7193	75.2851
NEc	0.50801	0.48988	0.22722	0.27205	0.29018	0.54951

(Note: T. ash = Total Ash, OM = Organic matter, T. Ash = Total Ash, K = Potassium, P = Phosphorus and Ca = calcium and MC = moisture contain, RFV index= Relative feed value index, TDN = Total digestible nutrient and NEc = Net energy consumed).

The value of NDF in this habitat was highest in *Gramineae* species (86.96%) which was followed by *Juncus thomsonii* (81.01%), *Rumex nepalensis* (62.12%). Rest of other have the value of NDF less than 50% and *Fragaria nubicola* had the lowest value (44.38%). The value of ADF was highest in *Gramineae* species (56.15%), which is followed by *Juncus thomsonii* (53.33%), *Rumex nepalensis* (52.19%), and *Viola wallichiana* had the least (35.88%).Acid Detergent Lignin was the highest in *Rumex nepalensis* (27.41%) that was followed by *Geranium nakaoanum* (24.7%), *Viola wallichiana* (23.97%), and the least in *Juncus thomsonii* (11.37%). Both *Juncus thomosnii* and *Gramineae* species had higher value of NDF, ADL and least value of ADL in this habitat (Fig 43).

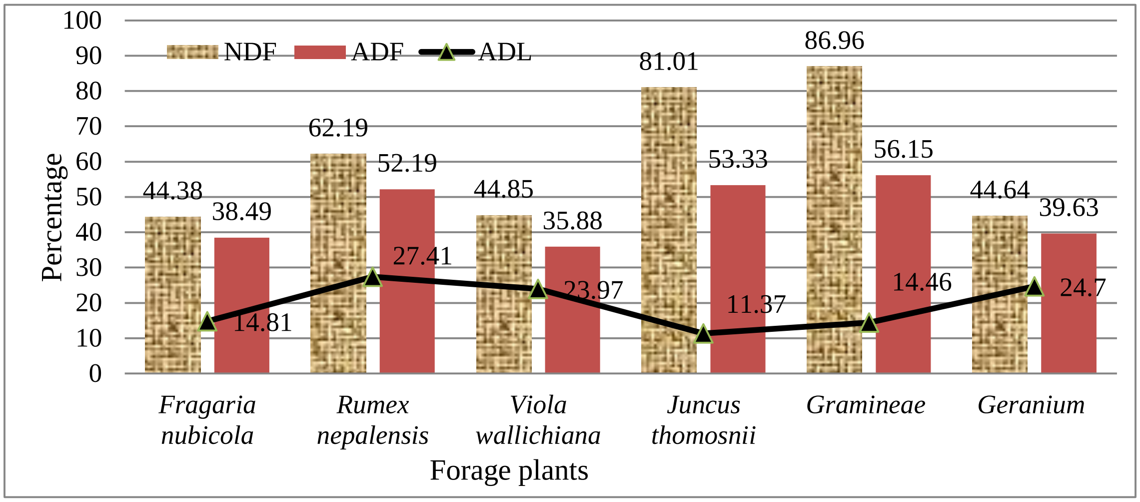


Figure 43: NDF, ADF and ADL content in major plants species of subalpine area in LNP.

The total organic matter was highest in *Juncus thomsonii* (95.14%) in this habitat. It was followed by *Gramineae* spp (91.78%), *Fragaria nubicola* (89.18%), *Rumex nepalensis* (88.38%) and *Viola wallichiana* (86.71%). The ratio of hemi-celluloses and cellulose in percentage was 5.9:23.68, 10.01:24.78, 8.98:11.91, 27.68:41.95, 30.8:41.69 and 5.01:14.93 in *Fragaria nubicola, Rumex nepalensis, Viola wallichiana, Juncus thomosnii, Gramineae* spp and *Geranium nakaoanum* respectively. *Rumex nepalensis* had the most protein (24.62%) and least was recorded for *Geranium nakaoanum* (Fig 44).

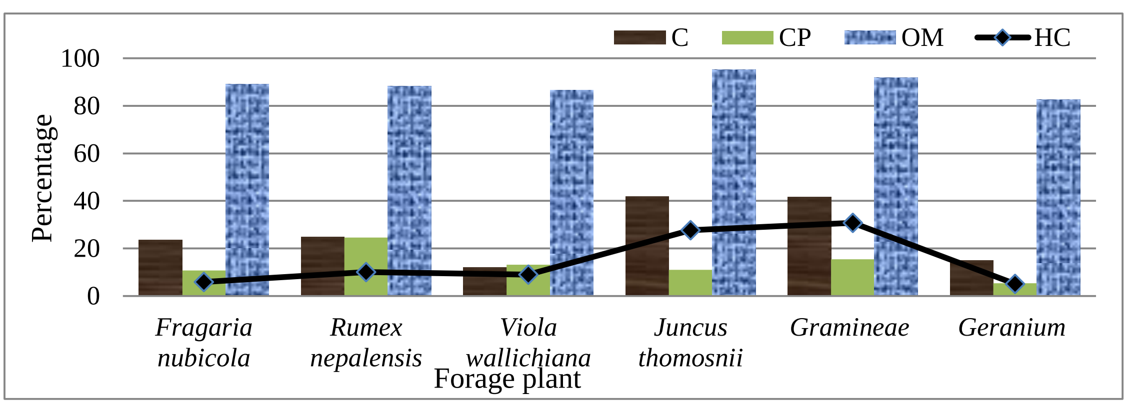


Figure 44: HC, C, CP and OM content in major plants of subalpine area LNP.

Phosphorus contain was highest in *Geranium nakaoanum* (1.22 mg/g), and the lowest was in *Fragaria nubicola* (0.45mg/g), among the six most consumed plants species in subalpine area. *Viola wallichiana* has the maximum value of potassium (24mg/g). *Rumex nepalensis* has 10.5mg/g (Fig 45), and least in *Fragaria nubicola and Juncus thomosnii* (2mg/g). The highest value of calcium was in *Geranium nakaoanum* (7.1mg/g). It was followed by *Gramineae* species (6.2mg/g), *Rumex nepalensis* (5.8mg/g), *Fragaria nubicola* (4.3mg/g), *Viola wallichiana* (2.5mg/g) and the least was in *Juncus thomosnii* (2.3mg/g).

In the habitat of subalpine with broken rocks the RFV index was maximum in *Fragaria nubicola* (1.13) that was followed by *Geranium nakaoanum* 1.127, *Viola wallichiana has* 1.119; *Rumex nepalensis* (0.605), *Juncus thomosnii (*0.296) and the least in *Gramineae* species (0.296). The total digestible nutrient value in *Fragaria nubicola, Viola wallichiana and Geranium* species was almost 75%: whereas *Rumex nepalensis* had 63.71%, *Juncus thomosnii* (51.16%) and the least value was in *Gramineae* species (47.19%). The Net energy consumption index of *Fragaria nubicola, Fragaria nubicola and Geranium nakaoanum* were in range from 0.49 to 0.55; and other three had the range of 0.22 to 0.29. In subalpine area *Gramineae* species was the most (6.45%) consumed species (in frequency), but it's all micronutrient value, Protein value, RFV index and NEc value was the least among the six consumed plant species (Table 14 and Table 10).

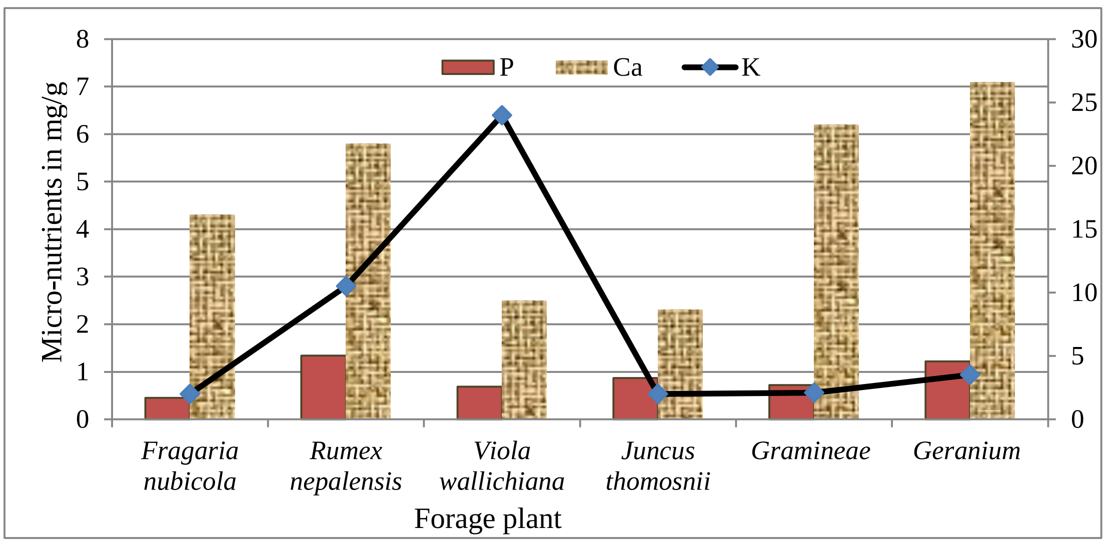


Figure 45: Micronutrients contain in major plants of subalpine area, LNP.

4.5.3 Nutrients in alpine and talus area

In Alpine talus area, the most frequency consumed six forage plants were *Apiaceae*, *Gramineae* spp, *Fragaria daltoniana, Ligularia amplllexicaulis and Pedicularis megalantha.* Among these plant species *Apiaceae* contain the highest (21.03%) total ash and lowest in *Potentilla peduncularis. Gramineae* species collected from alpine, talus area had the maximum moisture content (84.3%), and the least moisture was recorded in *Fragaria daltoniana* (72.76%) among six major plants species (Table 17).

Table 17: Nutritional value of the six most consumed plants species alpine and talus area, LNP

Nutrients	***Apiaceae* species**	***Fragaria daltoniana***	***Gramineae* species**	***Ligularia* Species**	***Pedicularis megalantha***	***Potentilla peduncularis***
T. Ash	21.03	7.8	9.48	16.07	18.45	7.2
OM	78.97	92.2	90.52	83.93	81.55	92.8
NDF	39.88	33.08	78.76	45.56	68.14	39.22
ADF	38.89	27.55	51.28	39.61	65.54	37.3
ADL	15.54	7.7	7.59	21.94	30.71	12.43
HC	0.99	5.53	27.48	5.95	2.6	1.92
C	23.35	19.85	43.69	17.67	34.83	24.87
CP	11.1	9.31	14.25	17.67	20.3	12.78
K	19	2.3	20	36	10.5	6.8
P	104.5	1	3.33	160	1.28	65.8
Ca	3.3	2.2	7	41	40	4.1
MC	92.41	79.68	88.45	90.17	83.49	82.14
RFV index	1.349	1.775	0.3253	1.090	0.4889	1.383
TDN	78.6	83.1356	52.667	74.8115	59.7506	79.0403
NEc	0.50165	0.68196	0.30464	0.4902	0.07791	0.52693

(Note: T. ash = Total Ash, OM = Organic matter, K = Potassium, P = Phosphorus and Ca = calcium and MC = moisture contain, RFV index= Relative feed value index, TDN = Total digestible nutrient and NEc = Net energy consumed).

The value of NDF in this habitat was highest in *Gramineae* species (78.76%) which was followed by *Pedicularis megalantha* (68.14%). Rest of other have the value of NDF less than 50%, and *Fragaria daltoniana* had the lowest (33.08%). The value of ADF was highest in *Pedicularis megalantha* (65.54%). It was followed by *Gramineae* species (51.28%), *Ligularia ampllexicaulis* (39.61%), *Apiaceae* species (38.89%), *Potentilla peduncularis* (37.30%) and least in *Fragaria daltoniana* (27.55%).Acid Detergent Lignin was the highest in *Pedicularis megalantha* (30.71%) that is followed by *Ligularia ampllexicaulis* (21.94%), *Apiaceae* species (15.54%), *Potentilla peduncularis* (12.43%) and least was 7.7% in *Fragaria daltoniana* (Fig 45). *Potentilla megalantha* was the plant only consumed in alpine habitat by pika had higher value of NHF, ADF and ADL. This plant was not recorded in quadrats from other habitats of the study area.

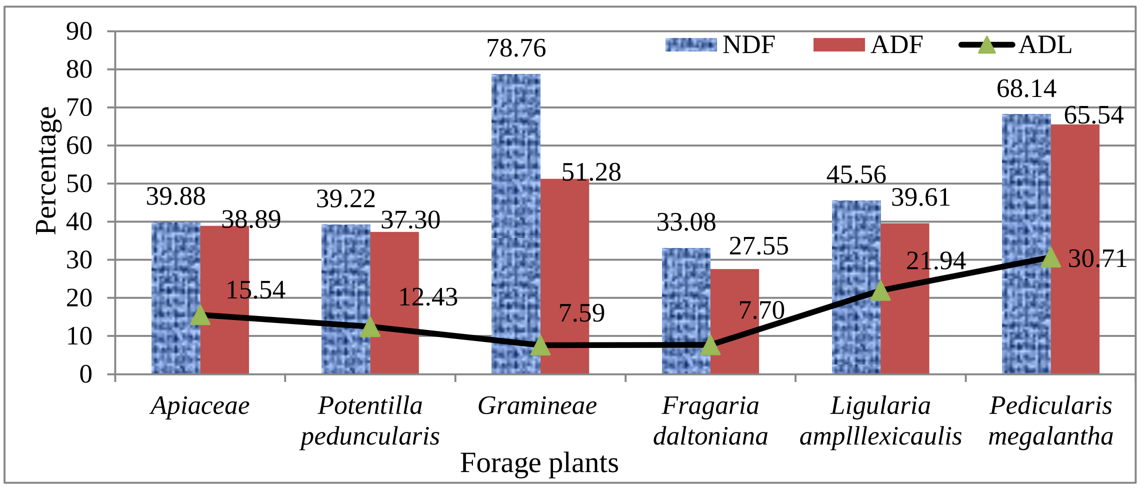


Figure 46: NDF, ADF and ADL contain in major plants of alpine and talus area, LNP.

Potentilla peduncularis, Gramineae species and *Fragaria daltoniana* had organic matter more than 90%. The value of total organic matter was followed by *Ligularia ampllexicaulis* 83.92%, *Pedicularis megalantha* 81.5% and the least in *Apiaceae* species (78.96%). The ratio of hemi-celluloses and cellulose in percentage was 0.98:23.34, 1.91:24.86, 27.48:43.68, 5.52:19.85, 5.94:17.66 and 2.59:34.83 in *Apiaceae* species, *Potentilla peduncularis, Gramineae* species, *Fragaria daltoniana, Ligularia ampllexicaulis* and *Pedicularis megalantha* respectively (Fig 47).*Pedicularis megalantha* had the highest value of protein (20.3%) among the major plants species and it was followed by *Ligularia ampllexicaulis* (17.67%) and *Gramineae* species (14.25%).

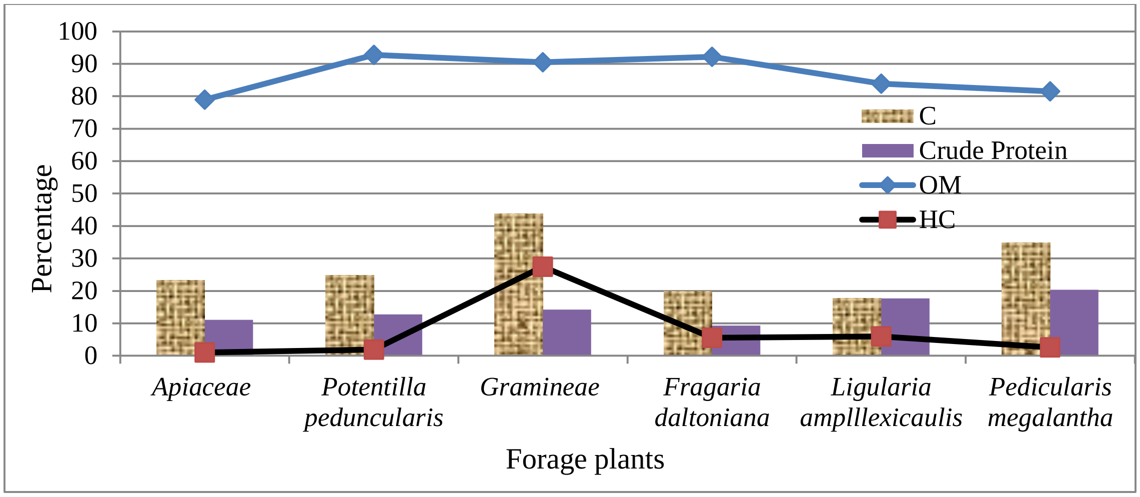


Figure 47: Cellulose, HC, CP and OM content in major plants of alpine talus, LNP.

In this study area, *Ligularia ampllexicaulis* contain the highest value of calcium (41mg/g) and potassium (36mg/g). *L. ampllexicaulis* is consumed by pika in al habitat but was consumed in highest frequency only in alpine talus habitat. *Pedicularis megalantha* contain second highest amount of calcium (40mg/g). It was followed by *Fragaria daltoniana* (22.5mg/g), *Gramineae* (7mg/g), *Potentilla peduncularis* (4.1mg/g) and the least in *Apiaceae* species (3.3mg/g). *Potentilla peduncularis* had very high value of phosphorous (65.8mg/g) in alpine talus area (Fig 48). It was followed by *Ligularia ampllexicaulis, which* contain 16mg/g of phosphorous then by *Apiaceae* species (10.5mg/g), *Gramineae* species (3.33mg/g), and *Pedicularis megalantha* (1.28 mg/g). The value of phosphorus (1mg/g) and potassium (2.3mg/g) was in *Fragaria daltoniana.* This plant was consumed by pika in all habitats but it was consumed in highest frequency in this habitat only.

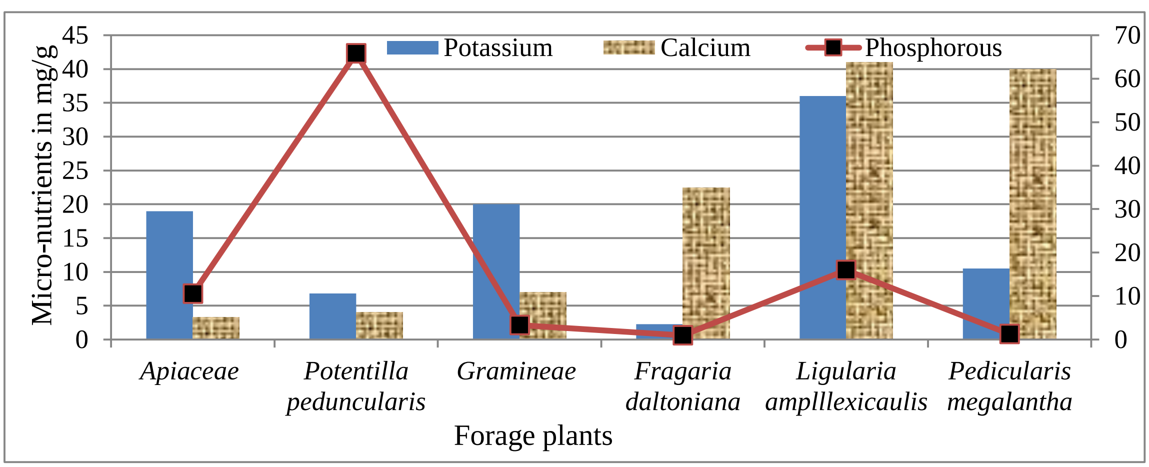


Figure 48: Potassium, Ca and P content in major plants of alpine and talus area, LNP.

In this study area, the RFV index was more than one in four forage plants species among six. *Fragaria daltoniana* (1.77) had the most value of relative feed value index and was followed by *Potentilla peduncularis* (1.38), *Apiaceae* species (1.34), *Ligularia ampllexicaulis* (1.09), *P. megalantha* (0.488) and *Gramineae* species had the least (0.32) as in other habitat. *F. daltoniana* had the total digestible nutrient (83.13%) it was followed by *P. peduncularis* (79.04%), *Apiaceae* species (78.60%), *L. ampllexicaulis* (74.81%) and the least in *Gramineae* species (52.66%). Here the plants like *Apiaceae* species and *L. ampllexicaulis* were large sized plant. The value of net energy consumed from the plants in habitat was the highest in *F. daltoniana* (0.68) and *Apiaceae* species, *P. peduncularis*, *Gramineae* species, *L. ampllexicaulis* and *P. megalantha* had the value 0.501649, 0.52693, 0.30464, 0.490201 and 0.077914 respectively (Table 16).

4.5.4 Nutrients in Gosainkunda Lake area

In Gosainkunda Lake premises the total ash content was highest in *Caltha palustris* (15.29 %,). The second highest was in *Ranunculus* species (11.55%) and least was in in *Juncus thomosnii* (5.59%) among six major plants species (Table 18). Moisture contain was the highest in *Caltha palustris* (84.3%). It was followed by *Botrichium* species (83.34%), *Juncus thomosnii* (78.92%), *Ranunculus* species (77.83%), *Gramineae* species (74.82%) and the least was in *Potentilla flugens* (72.83%).

Table 18: Nutritional value of major plants species in Gosainkunda Lake area, LNP

Nutrients	***Botrichium* species**	***Caltha* species**	***Gramineae* species**	***Juncus* species**	***Potentilla flugens***	***Ranunculus* species**
T.Ash	8.49	15.29	9.52	5.59	6.14	11.55
OM	91.51	84.71	90.48	94.41	93.86	88.45
NDF	67.02	48.67	79.43	79.83	38.38	49.93
ADF	66.18	40.95	56.46	61	34.55	40.35
ADL	29.54	14.55	15.53	11.48	3.45	25.64
HC	0.83	7.72	22.97	18.84	3.83	9.58
C	36.65	26.39	40.93	49.52	31.1	14.71
CP	10.54	10.6	15.24	9.81	15.97	12.27
K	17	19	12	1	2	4
P	4.1	3.2	0.81	2.66	2.66	1.15
Ca	40.7	33.8	7.2	40	25.2	4.2

MC	83.34	84.3	74.82	78.92	72.76	77.83
RFV index	0.50927	0.9745	0.316	0.311	1.43006	0.93162
TDN	60.4977	72.73	52.2202	51.95	79.6005	71.8967
NEc	0.06774	0.4688	0.22229	0.1501	0.57066	0.47844

(Note: T. ash = Total Ash, OM = Organic matter, T. Ash = Total Ash, K = Potassium, P = Phosphorus and Ca = calcium and MC = Moisture contain, RFV index= Relative feed value index, TDN = Total digestible nutrient and NEc = Net energy consumed).

The value of NDF in this habitat was highest in *Juncus thomosnii* (79.83%) which was followed by *Gramineae* species (79.43%), *Botrichium* species (67.02%), *Ranunculus* species (49.93%), *Caltha palustris* (48.67%) and the least in *Potentilla flugens* (38.38%). *Botrichium* species is recorded only in Gosainkunda Lake area. It had the highest of ADF (66.18%) and ADL (29.54 %). *J. thomosnii* had 61%, of ADF and *Gramineae* species (55.56%), *C. palustris* (40.95%), *Ranunculus* species (40.35%) and least in *Potentilla flugens* (34.55%). *P. flugens* had also the least value of Acid Detergent Lignin (Fig 49). In this habitat *J. thomosnii* and *Gramineae* species had highest value of NDF and ADL but the value of ADL was lower as in forest and its edge habitat. These both plants were consumed in all habitats by pika and again *Gramineae* species was consumed in highest frequency in all habitats.

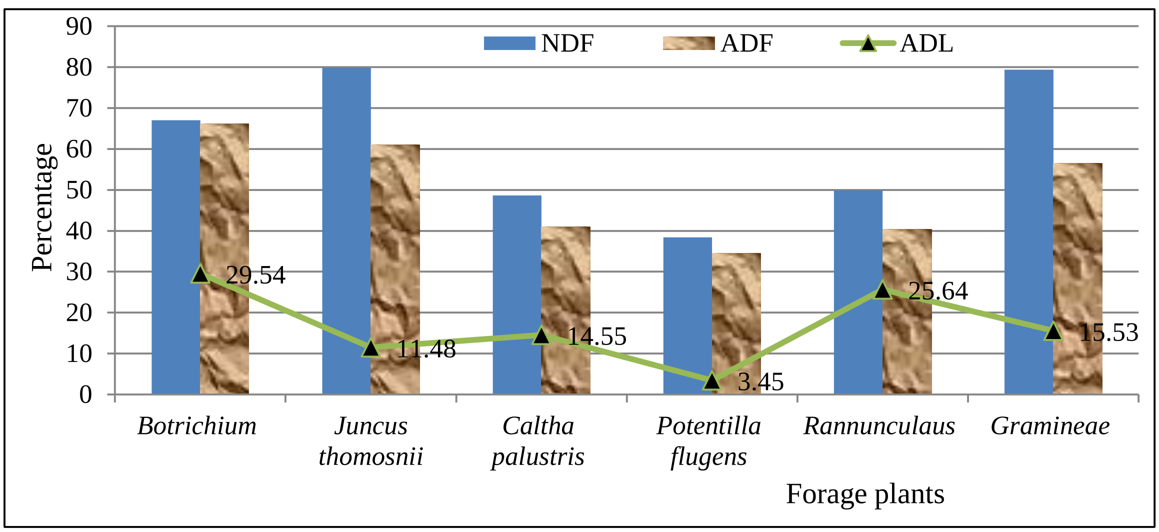


Figure 49: NDF, ADF and ADL value in major plants Gosainkunda Lake area, LNP.

The value of organic matter in Gosainkunda Lake foraged species were as following order: *Botrichium* species (91.51%), *J. thomosnii* (94.41%), *C. palustris* (84.71%), *P. flugens* (93.86%), *Rannuculus* species (88.45%) and *Gramineae* species (90.48%). The ratio of hemi-cellulose and cellulose was0.83:36.65, 18.84:49.52, 7.72:26.39, 3.83:31.1, 9.58:14.71 and 22.97:40.93 respectively in *Botrichium* species, *J. thomosnii, C. palustris, P. flugens*, *Ranunculus* species *and Gramineae* species(Fig 50). In this research site *P. flugens* was plant with more protein (15.95%) among six the most consumed plant species. It was followed by *Gramineae* species (15.24%), *Ranunculus* species (12.27%), *C. palustris* (10.65%), *Botrichium* species (10.54%) and the least in *J. thomosnii* (9.8%).

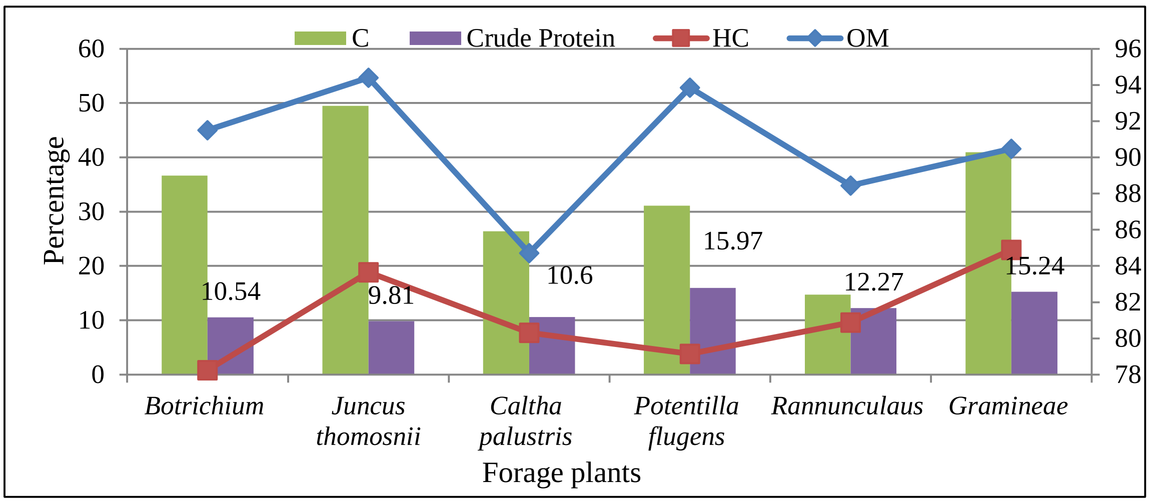


Figure 50: OM, HC, C and crude protein value in different plants Gosainkunda Lake area, LNP

Botrichium species consumed by pika only in this habitat had the highest value of calcium (40.7mg.g) and potassium (4.1mg/g). The calcium contain in *Juncus thomosnii* was 40mg/g, *Caltha palustris* (33.8mg/g) which were followed by *Potentilla flugens* (25.2mg/g), *Gramineae* species (7.2mg/g) and *Ranunculas* species had the least calcium (4.2mg/g). In Gosainkunda Lake area *C. palustris* had the maximum potassium (19mg/g), it was followed by *Botrichium* species (17mg/g), *Gramineae* species(12mg/g), *Ranunculas* species (4mg/g), *P. flugens* (2mg/g) and *J. thomosnii* had the least (1mg/g). The Phosphorous contain in these forage species were 2.66mg/g, 3.2mg/g, 2.66 mg/g, 1.15 mg/g and 0.81 mg/g in *J. thomosnii, Caltha palustris, P. flugens, Ranunculus* and *Gramineae* species respectively (Fig 51)

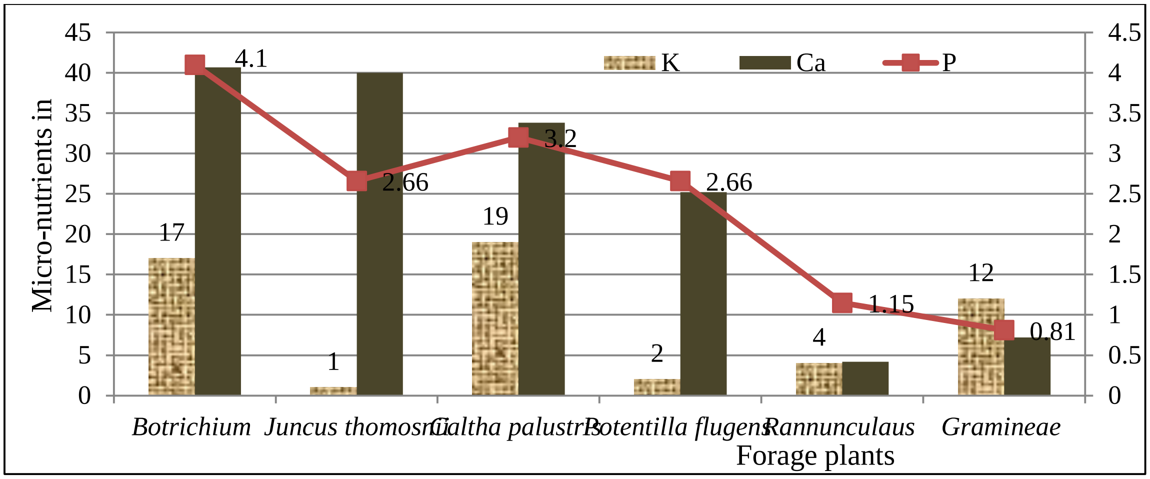


Figure 51: K, P and Ca values in different plants at Gosainkunda Lake area, LNP.

Potentilla flugens in this habitat had the most relative feed value index (1.43), total digestible nutrient (79.61%) and net energy consumed index (0.57). *Potentilla flugens* was the fourth highest consumed plant in Gosainkunda Lake area (6%). *Caltha palustris* had RFV index 0.9745 with TDN 72.73% and NEc 0.468. *C. palustris* was the third most consumed (6.85%) plant. Similarly, *Ranunculus* species had RFV index 0.93, TDN 71.89% and NEc 0.48, this was the fifth most consumed plant. *Gramineae* species was the least consumed in frequency between six plant species Its RFV index was 0.316, TDN 52.22% and NEc value was 0.22. The highest consumed plant species *Botrichium* (6.50%) had RFV index, TDN and NEc 0.50, 60.49 and 0.067 respectively (see Table 18)

4.5.5 Comparison between nutrients value at different habitat of LNP

The average elevation of all quadrats in forest and its edge area was 3256± 51.49 masl, SD 162.81, subalpine area with broken rock area was 3697± 26.32masl, SD 110.35, alpine talus area is 4359 ± 68 masl, SD 266.22 and Gosainkunda Lake area was 4377 ± 38 masl, SD 94.9. There were eighty-nine species of plants in four different habitats. Among them total sixty-seven species were consumed by pika. Eight species of plants were consumed in all habitats (study areas), 13 species in consumed in three habitats, 27 species were consumed only in two habitats and nine species were consumed only in single habitat (see Table 10, 11, 12 and 13). Among them *R. nepalensis*, *J. thomosnii, F. nubicola, G. nakaoanum and Gramineae* species were among the most consumed plant species in reference to consumed frequency.

a. *Rumex nepalensis* (Halhale)

Rumex nepalensis is erect plants, usually with long tap roots. It has fleshy to leathery broad-leaved arise from a basal rosette at the root. Its local name is 'Halhale', use as fodder for livestock, sheep and goats in high altitude. *R. nepalensis* was recorded only two habitats of study area and was consumed in highest frequency in both habitats: forest and its edge and subalpine area with broken rocks by pika in LNP (see: Table 10 and Table 11).

Table 19: Nutrients of *Rumex nepalensis* in different habitat in LNP

Habitat ⇨	**Forest and its edge area**	**Subalpine area with rocks area**
E elevation (m) ⇨	3256 ± 51.49 masl	3697 ± 26.32 masl
T. Ash	22.42	11.62
OM	77.58	88.38
NDF	58.10	62.19
ADF	57.83	52.19
ADL	36.40	27.41
HC	0.27	10.01
C	21.43	24.78
Crude Protein	12.9861	24.623
Potassium (mg/g)	5.8	10.5
Phosphorous (mg/g)	1.86	1.34
Calcium (mg/g)	11.6	5.8
MC	88.49	90.72
RFV index	0.698708	0.605035
TDN	66.44706	63.71701
NEc index	0.200519	0.290215

The comparative nutritional result shows there was increased in the value of organic matter by 11%, NDF% (4%), hemicelluloses (9.7%), cellulose (3%), crude protein (11.7 %) and moisture contain (2%) when elevation was increased. The rest of other nutrients like ADL decreased by 9%, calcium by 5.8% as elevation increases (Table 19) but in overall nutritional analysis, the relative feed value index (IFV), total digestive nutrient and net energy consumed for the *Rumex nepalensis* at both elevation was similar. The IFV was higher by 0.09 and TDN was higher by 2.7% at forest and its edge area but net energy consumed (NEc) was increased by 0.09 along with elevation.

The t-pair test of nutrients analysis of *Rumex nepalensis* for two respective elevation gives, there is no any significance change (t = 0.7329, df = 14, p-value = 0.4757, Here the p-value 0.4757 >0.05) in total nutrient contain as elevation altered by average 440m.

b. Juncus thomosnii

Among 58 forage species consumed by pika in Langtang National Park *Juncus thomosnii* was consumed in all habitats. *Juncus* is a genus of monocotyledonous flowering plants, commonly known as rushes. *J. thomosnii* was consumed most in frequency in two habitats: subalpine area with broken rocks and in Gosainkunda Lake area (see: Table 12 and Table 13).

Table 20: Nutrients of *Juncus thomosnii* in different habitat

Habitat ⇨	**Subalpine area**	**Gosainkunda Lake area**
elevation (m) ⇨	3697 ± 26.32 masl	4377 ± 38 masl
T. Ash	4.86	5.59
OM	95.14	94.41
NDF	81.01	79.83
ADF	53.33	61.00
ADL	11.37	11.48
HC	27.68	18.84
C	41.95	49.52
Crude Protein	11.0356	9.814473
Potassium (mg/g)	2	1
Phosphorous (mg/g)	0.87	2.66
Calcium (mg/g)	2.3	40
MC	72.73	78.92
RFV index	0.296205	0.311218
TDN	51.16755	51.95067
NEc index	0.272096	0.150174

J. thomosnii had the highest value of neutral detergent fibres (NDF) and acid detergent fibres (ADF), the least value of acid detergent lignin (ADL) among the six most consumed plats of that respective habitats. The comparative nutrients result of *J. thomosnii* at subalpine area and Gosainkunda Lake shows that total Ash, acid detergent fibres (ADF), Cellulose (C), Phosphorous (P), calcium (Ca) and moisture contain (MC) increases as elevation increased (Table 20). Calcium shows the remarkable change, as it was exceed by 37.7mg/g in Gosainkunda lake area than lower elevation.

Acid detergent lignin (ADL) value was almost no change. Neutral detergent fbres (NDF), hemi-cellulose (HC) and crude protein (cp) were decreased at higher elevation (Gosainkunda Lake area). The overall nutrients show no major change as elevation change. The *J. thomosnii* had IFV index changed by 0.02, TDN by 0.08% and 0.08 changed NEc only. When these all nutritional value were t-paired tested with elevation shows there is no significance (p-value = 0.237)

c. *Geranium nakaoanum*

Geranium nakaoanum was consumed by pika in all four habitats but it has high frequency consumed only in two habitats: forest and its edge area and subalpine area with broken rocks. The nutrients comparison shows the values of neutral detergent fibres (NDF) and acid detergent fibres (ADF), phosphorus, moisture contain, hemicellulose, crude protein, organic matter has no change but the value of other nutrients like acid detergent lignin (ADL), Crude protein, Potassium and Calcium were decreased as elevation increases in *G. nakaoanum* (Table 21).

Potassium and Calcium value is increased by seven times and 3.5 times as elevation increases. The amount of organic matter and moisture contain was constant in both habitat. The value of Potassium was seven times more in subalpine area. The overall IFV index was more in higher elevation by 0.22, TDN by 4.1% and NEc by 0.091. The t-pair test between nutrients of *Geranium nakaoanum* and elevation shows no significance relation (p value = 0.4954; t = 0.7, df = 14).

Table 21: Comparative nutrients of *Geranium nakaoanum* in different habitats of LNP.

Habitat ⇨	**Forest and its edge area**	**Subalpine area with broken rocks**
Elevation (m) ⇨	3256 ± 51.49 masl	3697 ± 26.32 masl
T. Ash	19.00	17.33
OM	81.00	82.67
NDF	50.72	44.64
ADF	45.77	39.63
ADL	15.99	24.70
HC	4.96	5.01
C	29.78	14.93
Crude Protein	4.300317	5.37916
Potassium (mg/g)	5	35
Phosphorous (mg/g)	2.91	1.22
Calcium (mg/g)	2.4	7.1
MC	82.32	80.01
RFV index	0.905731	1.127821
TDN	71.36785	75.42392
NEc index	0.392297	0.489869

d. *Gramineae* species

Gramineae species was only the plant species, which distributed in all elevation and were consumed the most frequently in all habitats. It was consumed 11.65% of total in forest and its edge, 6.45% in subalpine area with broken rocks, 6.31% in alpine talus area and 8.85% in Gosainkunda Lake area (Table 22). The value of total ash of *Gramineae* species was increased as elevation increases as 5.66%, 8.22%, 9.48% and 9.52% respectively in average elevation of 3256 masl, 3797 masl, 4528 masl and 4343 masl.

The value of NDF was highest at subalpine area. Its value was equal in forest area and alpine area. ADF% of *Gramineae* species was maximum (64.58%) at lower elevation and lowest (51.28%) in subalpine area. The value of ADL was very high (49.41%) at forest and its edge area where as its value was lowest in alpine talus area. Its value was equal in subalpine area and Gosainkunda Lake area. *Gramineae* species had more protein in subalpine area but its value was almost equal in all elevation (12.69%, 15.41%, 14.25% and 15.24% respectively).

Table 22: Comparative nutrients of *Gramineae* species in different habitat of LNP.

Habitat	**Forest and its edge area**	**Subalpine area**	**Alpine talus area**	**Gosainkunda lake area**	**p value**
Elevation (m)	3256 ± 51.49	3697 ± 26.32	4359 ± 68	4377 ± 38	
T. Ash	5.66	8.22	9.48	9.52	0.038
OM	94.34	91.78	90.52	90.48	0.038
NDF	78.39	86.96	78.76	79.43	0.805
ADF	64.58	56.15	51.28	56.46	0.156
ADL	49.41	14.46	7.59	15.53	0.160
HC	13.81	30.80	27.48	22.97	0.476
C	15.16	41.69	43.69	40.93	0.398
Crude Protein	12.691	15.41	14.25	15.249	0.398
K (mg/g)	2	21	20	12	0.435
P (mg/g)	1	0.72	3.33	0.81	0.513
Ca (mg/g)	5.7	6.2	7	7.2	0.006
MC	83.96	88.45	84.3	74.82	0.466
RFV index	0.330363	0.226385	0.325343	0.316511	0.814
TDN	52.91695	47.20079	52.66698	52.22137	0.805
NEc index	0.093214	0.227204	0.304647	0.222272	0.156

The value of calcium increases as elevation increases. The moisture contain was maximum in subalpine area (88.45%) and the least in Gosainkunda area (74%). The value of RFV index, TDN and NEc shows no more changes in *Gramineae* species along altitudinal gradient. The p-value of individual nutrients with elevation shows no significance relation between respective nutrient and elevation change except calcium (p value = 0.006), organic matter (p value = 0.038) and total ash (p value = 0.038). Only calcium shows the significant relation with elevation with p value 0.006. When all these nutritional values were tested for ANOVA test which gives the value p-value= 0.998. It shows there no significant between elevation and total nutritional value of *Gramineae* species of Langtang National Park.

In overall comparison, the value of potassium (10.5 to 35 mg/g) and calcium (5.8 to 40) were the highest in subalpine area for all consumed plants. For all the forage plants, the value of crude protein and hemi-cellulose were the highest in subalpine area too (see: Table 14, Table 15, Table 16 and Table 17). This shows plants in subalpine area were rich protein, carbohydrate and major minerals in comparison to other habitats. Therefore, subalpine area with broken rock habitat was the best to pika regarding the nutritional value of foraging plants.

4.6 Meteorological Data

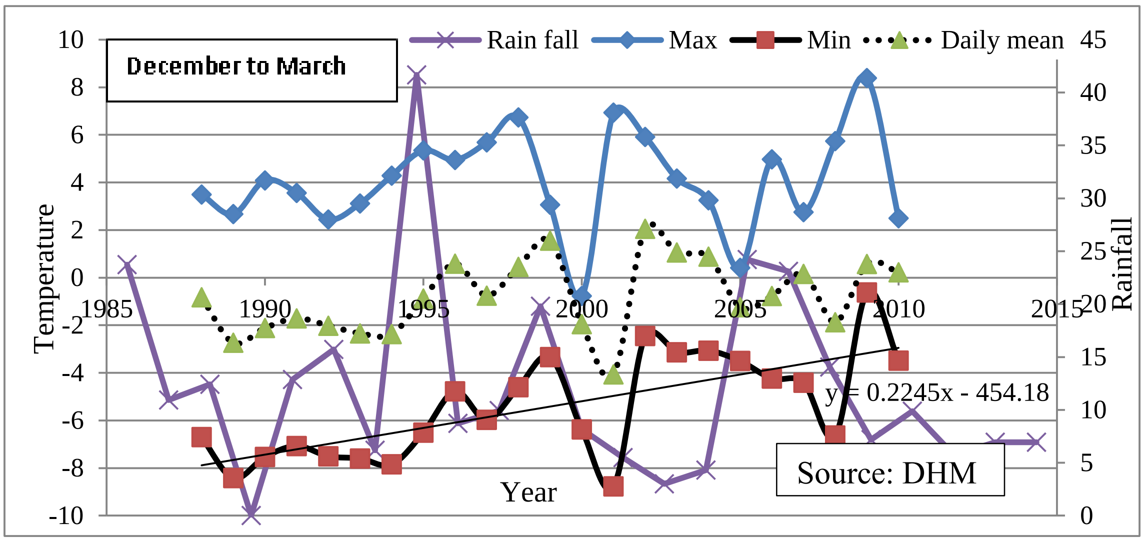
The record of temperatures and rainfall data of more than two decades (1987 to 2010) was used for analysis. Simple linear regression was used for qualitative assessments of trends in climatic parameters. The meteorological records were collected from Department of Meteorology and hydrology, Kyanging station, Langtang National Park (3980 masl).

Data were calculated monthly, furthermore divided for 12 months in three groups. Three groups were as December to March, April to August and September to November. First group of month (December to March) are the months with snowfall at that elevation, second group (April to July) are raining (monsoon) and months with high temperature and the last (September to November) months with less rain or no rain/snow.

4.6.1 December to March

This season was dry and very cold (average -5.41^0C) in Langtang. Langtang received snow from December to March. Snow play vital role in temperature variation. It reflects the light and heat (Aledo effect) and it work as insulator of heat inside the burrow. The mean maximum temperature of 23 years for this season is 4.07^0C, mean minimum is -5.41^0C and average mean is -0.79^0C.

Meteorological data from 1987 to 2010 of these months shows there no significance change in maximum temperature of Langtang. The p value of monthly mean maximum temperature was 0.5177 (> 0.05). Line trend with slope equation $y = 0.0435x - 82.838$ and $R^2 = 0.0202$ suggest the trend of the maximum temperature was not change along with time (years). The monthly mean average and monthly mean minimum temperature has the P values 0.048648 and 0.000238 respectively, which are, less than 0.05 so; the mean minimum temperature and mean average monthly temperatures were significant with the time. The slope equation for mean minimum temperature y= 0.2245x - 454.18 R^2 = 0.482 suggest that minimum temperature of these month is increasing. This is affecting the mean average temperature even mean maximum temperature is not changed. Similarly, the P value of rainfall P= 0.3488> 0.005 so there is no any significance change in rainfall (snowfall) and time in this season but the slope equation (y = -0.2789x + 15.562 and R^2 = 0.0419) with negative value suggest it is decreasing along time (Fig 52).



Maximum temp	Daily Mean temp	Minimum Temp	Rainfall
y = 0.04x - 82.83	y = 0.09x - 191.42	y = 0.22x - 454.18	y = -0.27x + 15.56
R^2= 0.0202	R^2= 0.1726	R^2= 0.482	R^2= 0.0419
P-value = 0.5177	P-value = 0.048648	P-value=0.000238	P-value= 0.348821

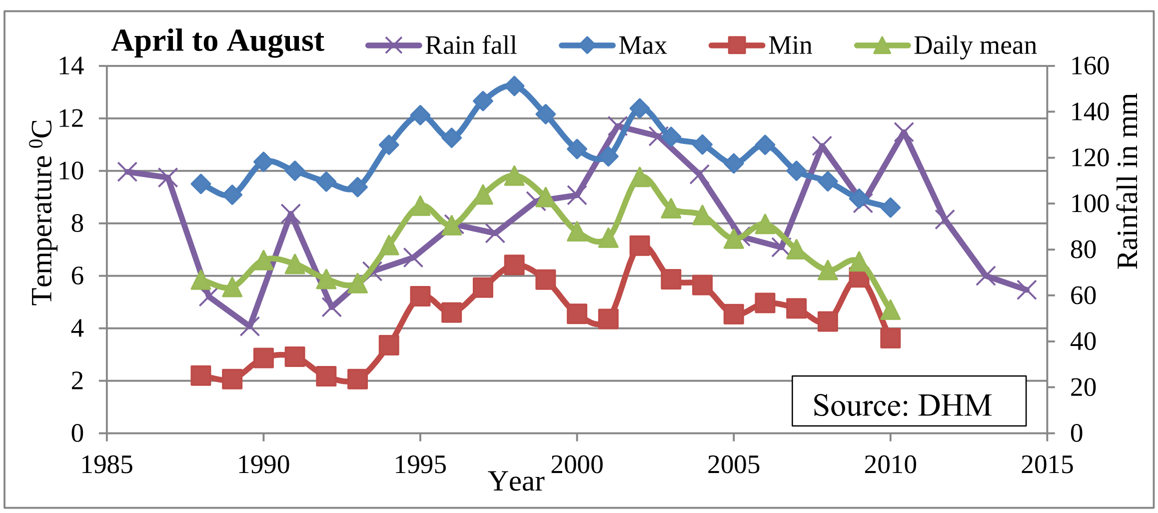
Figure 52: Temperature and rainfall pattern in December to March 1987 to 2010, LNP.

Similar analysis shows the minimum temperature in each month was significant with time as their p values were 0.000238, 0.017883, 0.009881and 0.004768 respectively for December, January, February and March respectively. The monthly wise mean maximum temperature, mean average temperature and rainfall are not significant with time as their P values are more than 0.05 (Annex B). From 1987 to 2010, in winter season (snow time) the highest maximum temperature was in 2010 (8.37^0C) and the lowest minimum temperature was -8.77^0C in 2001. The maximum rainfall of 41.65mm was recorded in 1995 while lowest in 2001 (3mm).

To explore the relation of rainfall and temperature pattern, linear model Poly1 (f(x) = p1*x + p2) and linear model Poly2 (f(x) = p1*x^2 + p2*x + p3) was done. It gave the result as following: The curve fitting between mean maximum temperature and mean rainfall gives the goodness of fit, R-square are 6.071e-006 and 0.04756 for linear model Poly1 and linear model Poly2 respectively. Similarly, the respective relation for mean minimum temperature and mean rainfall was R-square: 0.0009725 and R-square: 0.0621. This shows there is no significance (R^2>0.8) relation between temperature (both mean maximum and mean minimum) pattern and rainfall in Langtang in this season.

4.6.2 April to August

The time from April to August was the hottest time (average maximum temperature 10.64^{0}C) in Langtang National Park. It is the season of raining (monsoon season) with average rainfall (92.8mm). The average minimum temperature of this season is 4.38^{0}C and average mean temperature from 1987 to 2010 is 7.36^{0}C. Meteorological data from 1987 to 2010 of these months shows the highest rainfall was received in 2000 (133.8mm) and lowest in 1991 (46.8mm). The highest temperature was recorded in 1998 (13.23^{0}C) and lowest temperature of this season was in 1993 (2.06^{0}C).



Maximum temp	Daily Mean temp	Minimum Temp	Rainfall
y = -0.009x + 29.2	y = 0.027x - 48.47	y = 0.131x - 259	y = 0.703x + 84.36
R^2= 0.0025	R^2= 0.0182	R^2= 0.3567	R^2= 0.0353
P-value= 0.821	P-value = 0.5395	P-value=0.0026	P-value= 0.3904

Figure 53: Temperature and rainfall pattern in April to August 1987 to 2010 in LNP.

The meteorological data shows there is no significance relation between time and mean maximum temperature of this season as the P value of monthly mean maximum temperature 0.821162, which is > 0.05. The daily mean temperature and average rainfall has the P values 0.539519 and 0.390414 respectively, which are than 0.05 too, so these variables have no significance with the time (year). There is significance between average minimum temperature and time as the P value of average minimum temperature P= 0.002622< 0.005. The slope equation $y = 0.1318x - 259.07$, $R^2 = 0.3567$ suggest that the value of minimum temperature is increasing in this season (Fig 53).

The linear model Poly1 ($f(x) = p1*x + p2$) and linear model Poly2 ($f(x) = p1*x^2 + p2*x + p3$) in the curve fitting between mean maximum temperature and mean rainfall of this season gives the goodness of fit, R-square are 0.03105 and 0.0614 for linear model Poly1 and linear model Poly2 respectively. The mean minimum temperature and mean rainfall has the goodness of fit R-squares are 0.05196 and 0.05422. This shows no any significance relation between temperature (both mean maximum and mean minimum) pattern and rainfall in Langtang in this season. Similar analysis for average mean temperature gives the value, linear model Poly1 goodness of fit, R-square = 0.07008 and linear model Poly2 goodness of fit, R-square = 0.09001. These values also show there is no any significance between temperature and rainfall in summer (monsoon) season.

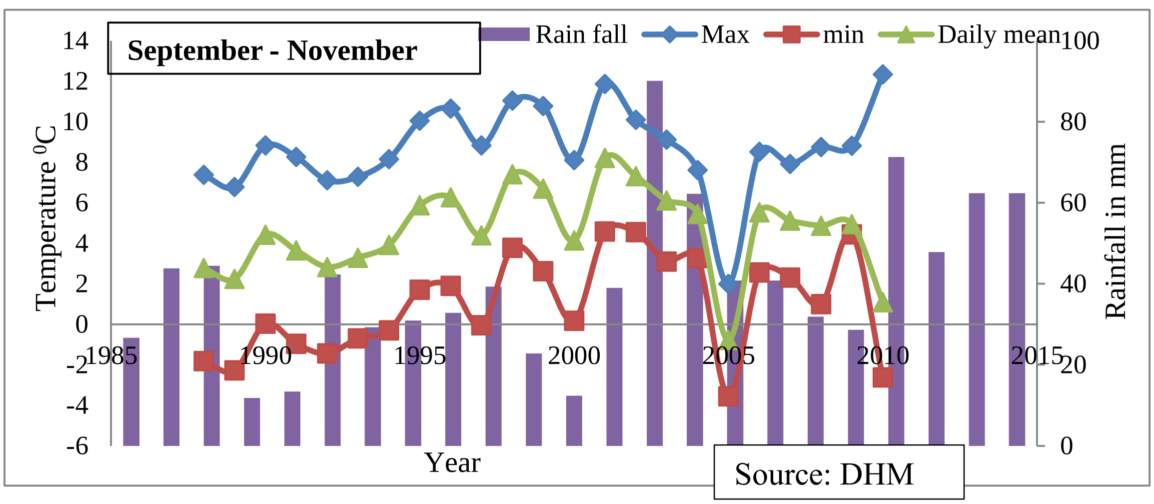
The monthly data analysis shows the value of mean minimum temperature has significance with time only in April and May with P values 00.0042 and 0.020043. The rainfall in April shows significantly increasing with time as p value 0.047711< 0.05. In the month of June, July and August, the entire variable had no significance with time (see Annex B).

4.6.3 September to November

The time from September to November is the season after monsoon and before snowfall in Langtang National Park. These months are not hot and raining as summer and cold and snowing as winter. Meteorological data from 1987 to 2010 of these months shows the highest rainfall was received in 2001 (90.2 mm) and lowest rainfall received in 1999 (12.2 mm). So it is neither dry as winter nor heavy rain as summer. The highest temperature was recorded in 2010 (12.34^0C) and lowest temperature in this season was in 2001 (-3.5^0C).

The meteorological data shows there is no significance relation between time with mean maximum temperature, average mean temperature and mean minimum temperature of this season as the P value were 0.518868, 0.616788 and 0.068663. However, the rainfall was significance to time with P value 0.016338respectively (Fig 54).

The linear model Poly1 (f(x) = p1*x + p2) and linear model Poly2 (f(x) = p1*x^two + p2*x + p3) in the curve fitting between mean maximum temperature and mean rainfall of this season give the goodness of fit, R-square: 0.07669 and 0.11 for linear model Poly1 and linear model Poly2 respectively. The mean minimum temperature and mean rainfall had the goodness of fit R-square: 0.1224 and 0.2598. This shows no significance relation between temperature (both mean maximum and mean minimum) pattern and rainfall in Langtang in this season. Similar analysis for average mean temperature gives the value, linear model Poly1 goodness of fit, R-square = 0.04337 and linear model Poly2 goodness of fit, R-square = 0.1028. These values also show there is no significance between temperature and rainfall in summer (monsoon) season.



Maximum Temp	Daily Mean Temp	Minimum Temp	Rainfall
y = -0.048x + 104.5	y = -0.015x + 35.9	y = 0.113x - 225.34	y = 0.84x + 28.11
R^2= 0.0156	R^2= 0.0024	R^2= 0.1107	R^2= 0.083
P-value=0.5188	P-value= 0.6167	P-value=0.06866	P value= 0.0163

Figure 54: Temperature and rainfall pattern in September - November 1987 to 2010 in LNP

The monthly data analysis shows the value of mean minimum temperature has significance with time only in November with P value 0.013**.** The remaining all the variables in this month and all the variables of September and November has no significance with time. It shows there is no change in this season (September, October and November) with different temperature pattern and rainfall in Langtang Himalaya (see Annex B).

The interesting phenomenon observed in this season is none of the month wise rainfall has significance rainfall with time (P-values of September was 0.189, October 0.082 and November is 0.196) but total mean rainfall was increasing and significance with time (1987 -2010). The mean minimum temperature in November is significant with time too. It shows the period of monsoon is extended to September and minimum temperature has significance relation which temperature drops in Langtang.

4.6.4 Temperature records from iButtons

Eighteen-temperature data logger (DS1921G Thermochrom iButtons, Maxim Integrated Products, Sunnyvale, CA, USA) were installed in pika's habitat in pika's habitat with in the permanent quadrats used to study population abundance and behaviour (burrow, 2-2.5 feet deep from surface) with difference of 200m elevation gradient in both route of Langtang National Park. It was set to record temperature inside the burrow in interval of 90 minutes as the temperature inside will change due to insulation effect of snow cover as well protection from direct sunlight. The lowest elevation of iButtons was at 3000 masl in Ghodatabela and highest elevation was in 4600 masl near Suryakunda and in glacier above Kyanging. Among 18 iButtons, four were lost (intentionally removed or stolen) and two stopped working after recording temperature for one year. Remaining all iButtons record the temperature of respective elevation and location from 2012 January to 2013 December. For 2012 the setting of iButtons were done as it record the temperature in interval of 90 minutes but for 2013 it was set for interval of 4 hours as there was no huge variation in 90 minutes intervals. The records of 3000masl (Ghodatabela), 3500 masl (Langtang valley), 3980 masl (Kyanging near meteorological station) and 4600 masl (above Kyanging glacier) was used for data analysis.

4.6.4.1 Monthly mean maximum temperature along elevation

The graph plot on mean monthly maximum temperature of four different elevations (3000masl, 3500masl, 3980masl and 4600masl) in Langtang does not shows that temperature decreases along altitude gradient in all seasons. The maximum temperature records in summer and winter shows the different patterns. From May to October (time after snowmelt to new snowfall), have highest temperature at 3980 masl elevation. In this time, the temperature increases according to elevation increases except in the elevation of 3980masl. The maximum temperature was in May (19 ℃ in 2012 and 16.5 ℃ in 2013) which was followed by July, August, June, September and October at 3980 masl.

November to April (from snowing to before snow melting months) the temperature is highest at Langtang valley (3500 masl). The highest temperature in this season was 12.5^{0}C in December and lowest mean maximum was 6.5^{0}C in February (this is also highest of that month among all elevation) at elevation in 2013. Regarding maximum temperature along elevation gradient shows elevation between 3500 masl to 3980 masl is warmer both in summer and winter inside the burrow (location of iButtons installed). The temperature at 3980 masl is more in summer (average 15.2^{0}C) than lower elevation of 3000 masl (average 13.34^{0}C). The maximum temperature at 4600 masl (average 7. 2^{0}C) is also higher than 3000masl (average 6.01^{0}C) in winter (Fig 55).

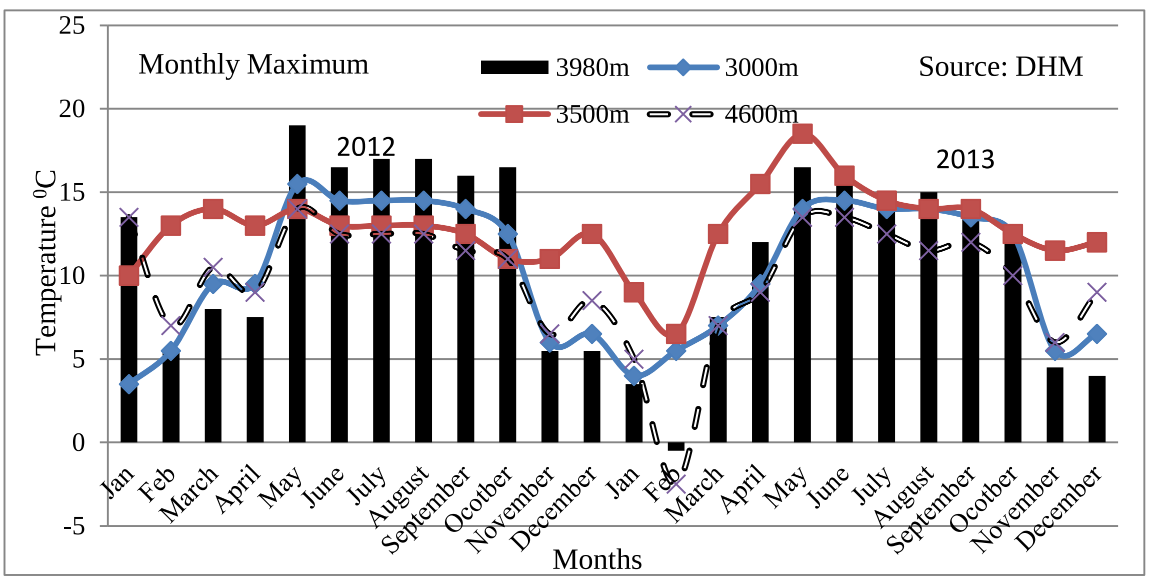


Figure 55: Monthly maximum temperature recorded in iButtons at different elevations of LNP.

It suggests that maximum temperature at higher elevation is higher than lower elevation in both seasons inside the burrow. This data do support the insulation inside the burrow, as there is no lower the temperature as elevation increases. The ANOVA test on elevation and mean maximum temperature gives the p value 0.073872 at df 95 (3:92). Since p value is higher than 0.05 the result is not significance. There is no significance relation between monthly mean maximum temperatures along altitudinal gradient.

4.6.4.2 Monthly mean average temperature along elevation gradients

The altitudinal mean average temperature of four different elevations in Langtang showed different pattern of temperature too (Fig 56). From mid of June to mid of October (monsoon time) had the highest mean average temperature at 3000 masl elevation the lowest elevation. The mean average temperature from 3500 masl to 3980 masl has equal values.

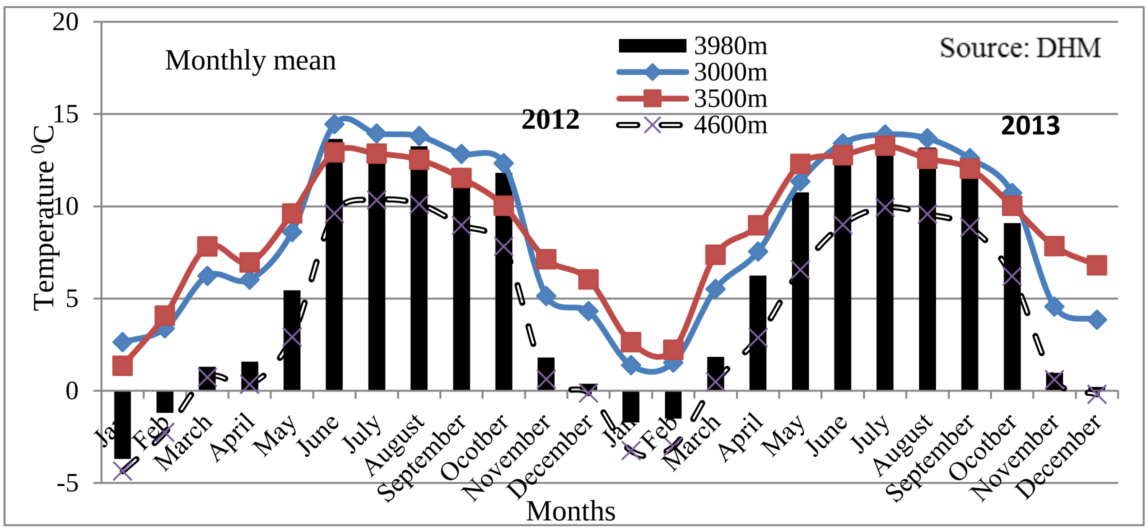


Figure 56: Average monthly mean temperature at different elevations, LNP

In this time, the temperature at 3500 masl and 3980 masl was almost similar. The mean average temperature at this elevation was warmer in both summer and winter. The maximum temperature in summer at 3500 masl was 12.93^{0}C (May) and least was 2.23^{0}C in February but the minimum temperature of other elevation was below zero in winter (Fig 56). This show mid elevation range of Langtang was warmer in winter and summer but higher elevation and lower elevation had high average mean temperature in summer and low in winter. January and February were the coldest months in average in all elevations.

The ANOVA test for time, elevation and mean maximum temperature was significance. The p value of these variables was 0.002139 at df 95 (3:92).

4.6.4.3 Monthly mean minimum temperature along elevation.

The graph between monthly mean minimum temperature of four different elevations in Langtang show that temperature decreases along altitude increases in all seasons (Fig 57). The mean minimum temperature was highest (average 7.31^{0}C) in lower elevation 3000 masl and lowest at higher elevation 3.18^{0}C at 3500 masl, 1.85^{0}C at 3980 masl and -0.958^{0}C (average) at 4600 masl. The iButtons inside the burrow at different elevation shows the mean minimum temperature decreases along elevation increases except April and May 2012.

The mean minimum temperature was 10^{0}C - 12^{0}C at mid elevation range (3000m to 3500m). The monthly mean minimum temperature was below -5^{0}C at 3980masl and 4600 masl in December, January, February and March.

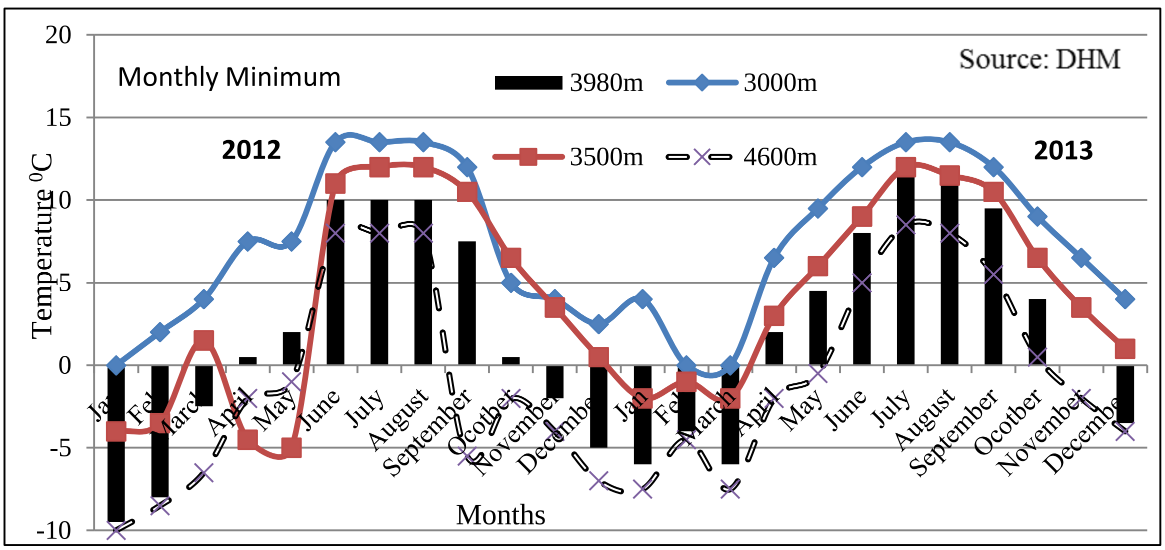


Figure 57: Monthly maximum temperature at different elevations

The records show 3.2^{0}C (0.64^{0}C/100m) changed from elevation of 3000 masl to 3500 masl. Similarly it was 2.25^{0}C (0.46^{0}C/100m) in between 3500 masl and 3980 masl and 2.81^{0}C (0.453^{0}C/100m) in between 3980 masl to 4600 masl.

The ANOVA test for time, elevation and mean minimum temperature shows significance relation as the p value 0.000111 at df 95 (3:92)

Table 23: Comparison between Ambient temperature and temperature inside burrow (recorded by iButtons) at elevation of 3980 masl.

Time	**Temperature of 2012**						**Temperature of 2013**					
	Maximum		**Mean**		**Minimum**		**Maximum**		**Mean**		**Minimum**	
Location	**Ambient**	**burrow**	**Ambient**	**burrow**	**Ambient**	**burrow**	**Ambient**	**burrow**	**Ambient**	**burrow**	**Ambient**	**burrow**
January	7.9892	10.5	2.6752	-2.699	-0.142	-9.5	4.20	3.5	-1.125	-1.717	-3.9832	-6
February	4.1606	5.5	-1.1688	-1.196	-4.1768	-8	3.09	-0.5	-0.680	-1.5	-3.4115	-4
March	3.0592	8	-0.7896	1.308	-3.646	-2.5	6.51	7.5	2.6362	1.833	-0.1876	-6
April	6.4308	7.5	2.4988	1.581	-0.4424	0.5	9.84	12	5.8295	6.23	3.2791	2
May	9.7524	19	5.688	5.445	3.0084	2	10.52	16.5	7.269	10.75	4.8229	4.5
June	10.487	16.5	7.186	13.65	4.6496	10	12.42	16.5	9.083	12.35	7.238	8
July	12.360	17	9.0264	13.22	7.112	10	11.79	15	9.082	12.91	7.3928	11.5
August	11.797	17	9.0956	13.25	7.3522	10	11.79	15	9.082	13.18	7.3928	11
September	11.797	16	9.0956	12.04	7.3522	7.5	11.32	14.5	7.575	12.49	5.9256	9.5
October	11.292	16.5	7.58	11.80	5.8644	0.5	8.619	13	4.970	9.089	2.8685	4
November	8.608	5.5	4.9322	1.796	2.704	-2	8.088	4.5	2.754	0.968	0.057	0
December	6.0968	5.5	1.0393	0.384	-2.038	-5	6.153	4	1.039	0.215	-1.8445	-3.5

Table 24: Total days in respective months with the temperature below -5^{0}C

Time/year	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Average 2002-2010**	**2012 iButtons**	**2013 iButtons**	**iButtons average**
January	-	26	30	30	26	15	16	24	17	23	26	24	**25**
February	-	28	22	22	28	17	24	26	21	23.5	26	22	**24**
March	-	23	5	5	10	18	14	12	8	11.875	3	-	3
April	-	-	2	2	2	1		3	2	2	-	-	
October	1		5	-	-	-	-	-	-	3	-	-	
November	9	4	13	-	8	7	7	3	-	7.28571	-	-	
December	21	26	11	-	19	14	8	10	-	15.5714	-	-	

4.6.4.4 Comparison between Ambient and inside burrow temperature

The comparison between monthly mean maximum, monthly mean minimum and monthly mean average in ambient air temperature and inside burrow shows was done. The difference between average two years mean maximum between ambient and burrow temperature was 2.407^{0}C. Its value of average mean was 1.377^{0}C and means minimum was – 0.526^{0}C. Here burrow serves as warmer than ambient temperature except for the condition of minimum temperature. The comparative data shows maximum temperature was warmer inside the burrow than ambient except in winter months of January February and December (Table 23). In these cold months, the burrow temperature goes decreases more than ambient temperature in all variables: maximum, minimum and mean temperature. Regarding minimum temperature its values is always less than ambient temperature in burrow. Monthly mean minimum was dropped to -3.5^{0}C - 9.5^{0}C when ambient temperature of these months was -1.8^{0}C to - 0.142^{0}C. These shows in winter burrows were getting colder than ambient temperature and unable to serve as heat insulator for pika habitat.

4.6.4.5 Acute heat and cold stress

To explore the acute heat and cold stress the temperature below -5^{0}c and above 20^{0}C from 2002 to 2010 was calculated. Meteorological data shows there were average 107, 88, 59, 93, 72, 69, 78 and 79 days from 2003 to 2010 with the temperature below -5^{0}C, which were 23 (74.19%) days, 23.5(83.92%), 11.8750.38%), 1.710.05%), 3.(09%), 6.37 (20.56%) and 13.62 (43.39%) days in average for January, February, March, April, October, November and December. Acute cold stress was the maximum in January February and December. But temperature inside burrow shows there were no any days in 2012 and 2013 below -5^{0}C except 26 days, 26 days and 3 days respectively in January, February and March 2012 and 24 days in January, 2013 and 22 days in February in 2013. The average days below -5^{0}C inside the burrow were more than ambient (Table 24). In Langtang National Park, there was not a single day with the ambient temperature more than 20^{0}C from 2002 to 2013. So in comparison to acute heat stress and acute cold stress; there is no evidence of acute heat stress and high fluctuation in maximum temperature but the acute cold stress was significant in winter especially in January and February. The number of acute cold days (days below -5^{0}C) was increasing similarly the temperature inside the burrow in these two months was decreasing too. Thus, acute cold stress on pika was increasing in Langtang National Park. Acute cold stress may cause local extirpation of pikas from Langtang National Park.

4.7 Discussion

4.7.1 Pika diversity and abundance

Kawamichi (1968) had studied winter behaviours of *Ochotona roylei* in Gosainkunda Lake side. He explained pika pellet were observed from 2800 masl as the lowest elevation of pika presence. He also reported presence of two species of pika in Langtang region. On the same year 1968 (May to July) another researcher from Hokkaido University, Abe (1971) did small mammal research in Central Himalaya of Nepal. He reported three species of pika (*Ochotona macrotis*, *Ochotona roylei* and *Ochotona* species) from different part of Langtang National Park. Abe had reported presence of *Ochotona macrotis* only from Gosainkunda Lake area, 4300m. He captured single male individual and identify with the help of skull structure and measurement. He reported the *O. macrotis* specimen was collected in a slide rock area in Gosainkunda together with specimens of *O. roylei* and confirmed the co-existence or sympatric of two species in this area. Specimens of *O. roylei* were captured and observed in Gosainkunda Lake area and Thadepati proper. Abe reported two adult females from Gosainkunda had already given birth to the young and had placental scars in the uteri, the number being three and two, respectively in mid-June 1968. The third species reported by him was from Ulleri (2180 masl), May 12, 1968. Its measurements was: Body weight 92gm, head and body 175mm, hind foot 34mm, ear 22.5mm, occipitonasal 38.9mm, condylobasal 35.7mm, palate 14.8mm, diastema 7.3mm, upper tooth row 7.8mm, bullae 7.8mm, nasals 13.0mm, frontals 5.5mm and mandible 26.8mm. The specimen examined is a young male, which seems to have been born early in the breeding season of the year taken. It had similar colour to that of the young of *O. roylei*. A large mature adult, which was observed at the same habitat, had a rufous coat similar to the summer coat of the later species. The form of the skull of the present specimen was also similar to it, but the fronto-parietal suture is V-shaped and rather resembles that of *O. macrotis*. He suggested these characters are different from *O. roylei* and *O. macrotis*. The elevation of the species occurrence was at 2180 masl.

Khanal and Shrestha (2000) had reported two species of pika (*O. roylei* and *O. macrotis*) in Langtang region. They observed 81 individuals of pika, among them 15 were *O. macrotis*. They had reported the observation of three individuals of Royle's pika (*O. roylei*) at Lama Hotel area (2800 masl) as lowest elevation of pika occurrence in June 1999. The team of researcher led by Dr. T. Yasunaga, a JICA volunteer, who was working in Natural History Museum, Nepal in June 2006 had reported the observation of two species of pikas too in this region Deo et al., (2008) did exploration on pika in 2008 and observed the two species of pika. The lowest elevation of pikas they observed in those periods was 2900masl above Lama Hotel in the route of Langtang-Kyanging.

In the current study, two species of pika were observed in Langtang National Park. *O. roylei* were found all habitats but *O. macrotis* were not observed in forest and its edge area. The lowest elevation of pika observation was different in different aspect of Langtang National Park. It was 3005 masl in Dimsa west North of Gosainkunda route, 3065 masl Magingoth on South of Gosainkunda route and 3010 masl of Ghodatabela (North-West) in Langtang route. The species diversity was identified by study of morphological characters such as body size, colouration, pinna size and presence and absence of thick clad in external ear. The third species explained by Abe (1971) may be the forest dweller *O. roylei* but the lowest elevation of its presence was very different from his previous research (Kawamichi, 1968) and researchers after him too. So, it cannot be concluded easily about the presence of third species of pika in Langtang National Park. The lowest elevation of pika observation record is increasing with the latter time. Pika used to observe at elevation of 2800 masl or lower before 1968 but they are not seen below 3000 masl during our study period. This suggests that either pika migrating upward or are locally extinct in lower elevation.

Consensus has been not reached on the systematic of *Ochotona* species; in fact, no revisions of all or part of the genus are remotely similar (Smith et al., 1990; Yu et al., 2000). Authors like Gureev (1964); Corbet (1978) include the large-eared pika *O. macrotis* within

O. roylei. There was much considerable confusion as to which sub-specific forms to include in *O. roylei*. The form *O. nubrica* was included in *O. thibetana* by Corbet (1978), and placed the form *O. forresti* in *O. roylei*. Mitchell and Punzo (1975) also used the term *O. lama* to *O. roylei*. The species described as *O. angdawai* (Biswas and Khajuria, 1954) and *O. mitchell* (Agrawal and Chakraborty, 1971). It was again synonymized with Royle's pika by Corbet (1978). The named forms *O. baltina* and *O. chinensis* have sometimes been assigned to *O. roylei*, but on the basis of study of both holotypes, Smith et al. (1990) concluded that they belong within the large-eared pika (*O. macrotis).*

Lissovsky (2014) did Taxonomic revision of pikas *Ochotona* (Lagomorpha, Mammalia) at the species level and explained the setting aside different taxonomic perspectives as 46 (about 4% of total) of the specimens in the test sample were misidentified. The greatest numbers of mistakes were for 17 (36.9%) samples, involved *O. macrotis* and *O. roylei*. He further suggests, specimens of *O. macrotis* and *O. roylei* form two weakly overlapping clouds. *O. macrotis* and *O. roylei* appear to have parapatric ranges. The specimens of *O. macrotis* and *O. roylei* display differences in their fur colouration; skins of *O. roylei* are more rufous with light under parts, whereas *O. macrotis* are browner without sharp differences between the dorsal and ventral parts. This observation was reported by Kawamichi (1971a) and (Smith et al., 1990). So morphological study requires additional careful investigation taking into account the age and molt stage of specimens (Lissovsky, 2014). The only distinctive morphological difference between these two groups appears to be that the vibrissae are longer in talus dwelling pikas, whereas the claws are straighter and more powerful in burrowing pikas (Fedosenko, 1974; Formozov, 1981). The many morphological similarities among forms and the difficult access to their habitats have been the major obstacles to their systematic. For diversity of pika, species in Langtang and its altitudinal migration required molecular (phylogenetic) research for species conformation.

O. roylei is reported from Kanchanjunga Conservation Area, the eastern part of Nepal to all parts of Nepal Himalaya (Biswas and Khajuria, 1954; Kawamichi, 1968; Abe, 1971; Mitchell and Punzo, 1975; Suwal et al., 1995; Khanal et al., 1999; Shrestha, 2003; Khanal, 2007; Koju et al., 2011) to Api Nampa CA the far west of Nepal (Koju and Chalise, 2013).

The distribution of *Ochotona macrotis* is reported only from Sagarmatha National Park, Langtang National Park and Makalu Barun National Park (Kawamichi, 1968; Abe, 1971; Kawamichi, 1971b; Mitchell and Punzo, 1975; Suwal et al., 1995; Shrestha, 2003; Koju et al., 2011; 2012c; Koju and Chalise, 2013). They were not reported west of Langtang except by Shrestha (2003) in Rara National Park and in Mustang near boarder with Tibet China (Durette-Desset et al., 2010). The book "Wildlife of Nepal" (Shrestha, 2003) is academic collection of mammals in Nepal which explain possible distribution of pika *O. macrotis* in Rara National Park. Rara National Park has majorly alpine evergreen forest with very less alpine talus area. Similarly, the sample used by Durette was single, and used its morphological information for speciation. Pika research especially in Uttarakhanda of India (Bhattacharya et al., 2009; Joshi, 2009; Haleem et al., 2012), west of Nepal did not explain about presence of Large eared pika in that area. Some researches as Abe (1971) in Manang and Mustang; Oli et al., (1993) in upper Mustang, Shrestha et.al., (1999) in Achham and Kalikot district of far west Nepal, Khanal (2007) at Ganesh Himalaya area of central Nepal, Khanal et al., (1999) in Bajura, Far West Nepal and Koju and Chalise (2013) in Api Nampa Conservation area, did not report about presence of *O. macrotis* even west of Bhote River (the of tribute Trisuli; Somewhere it is also known as Kerung khola) join with Langtang river near Syafrubesi then Trisuli river at Dhunche of Langtang. This suggests that the Bhote River, the river flow from Tibet to Nepal at central Himalaya, flows as west boundary of Langtang National Park may be the possible western most boundary for distribution of *O. macrotis* in Nepal.

Bhattacharya et al., (2009) had recorded mean density of Royle's pika 15.3 individual per ha in Uttarakhanda, Western India. Similarly Kawamichi (1968) and Smith et al., (1990) found the density of Royle's pika 14.1 and 12.5 per ha individuals respectively in Nepal. Koju and Chalise (2013) reported the population density of pika in Api Nampa Conservation area was 7.2 per ha in July 2012 and 8 per ha in July 2013. Haleem et al., (2012) recorded the mean density of Pika was maximum 48.442/ha in tree-line region and minimum 20.761/ha in alpine region of Kedarnath WildLife Sanctuary (KWLS). He further concluded the results was not significant and the density different along different altitudinal ranges of KWLS. The mean density of Pikas was maximum 60.55/ha along 3001-3300 masl altitude and minimum 14.82/ha along 3301-3600 m altitude. The population density of *O. roylei* in the current study was 4.8 individual per ha in forest and its edge area, 12.13 in subalpine area (with maximum 16.8/ha and minimum 10.8 per ha) and 7.86 individual per ha in alpine area (with maximum 18.8/ha and minimum 2.4/ha) with average mean 11.6 individual per ha. This is less than the population density mentioned by Kawamichi (1968) and Smith et al., (1990) for Nepal and Bhattacharya et al., (2009) in Uttarakhanda. Population density of pika in Langtang is very less than the Indian population density observed. Polulation density along elevation gradient is just opposite to that information (Haleem et al., 2012). In Langtang, Population density of *O. roylei* was maximum (16.8/ha) in subalpine area (3500 masl to 3900 masl) followed by Apline area with density 7.86 individaul per ha and the least in forest and its edge area (4.8 individual per ha in 3000masl to 3500masl). Population density of *O. macrotis* was highest in Apline talus area (10.47 individual per ha) and least in subalpine area (8.8 individual per ha). Here the population density explain by Haleem et al., (2012) and Bhattacharya et al., (2009) are three times (15/ha and 48.44/ha) different in same study area in interval of three years. Thus, there should have some methodological problem. Bhattacharya et al., (2009) concluded in his study that pikas were relatively more abundant at man-made walls in the alpine zone and on broken slopes in the subalpine zone. The highest relative abundance was recorded around the man-made walls in June and on broken slopes in May. The lowest relative abundance was found in alpine meadows in October and November 2008. This phenomenon was explained by Kawamichi (1968) in Gosainkunda region. This is similar to current research as the density of *O. roylei* was the most in subalpine area with broken rocks. It was the maximum in summer and rainy season and the least at dry/winter season. Regarding population density recorded by Kawamichi (1968) was 14.1 in Gosainkunda region and 12.5 by Smith et al., (1990), we can conclude population density of pika in Langtang is decreasing. The research of Kawamichi (1968) was in winter and dry season; while in current study population density at this season is less than five individuals per ha.

Southwick et al., (1986) reported that the populations of *Ochotona princeps* in the Colorado rokies had shown relatively consistent densities and stability over eight years of study. The study in three different sites have shown that the mid-August densities varied from 3.4 to 9.9 pikas/ha, and annual population fluctuations averaged less than 30%. American pikas occupy individual territories at low density (8–10/ha) on talus habitat.

Morrison et al., (2004) explained forage selection by collared pikas; under varying degrees of predation risk; that the population of Collaris pika (*Ochotona collaris*) as tripled during the course of study from 1.5 pikas/ha in 2000 to 4.7 pikas/ha in 2002. There is no significant difference in territory size between males and females, although males are more likely to roam around the talus beyond the confines of their territory than females. Territory size remains remarkably constant across the geographic range of the species. The nearest neighbor distances of this species between centers of activity on territories range is about 14 m to 30 m (Smith and Ivins, 1984; Smith and Weston, 1990). Plateau pikas (*Ochotona curzoniae*) live in social family groups on alpine meadows across the Qinghai-Xizang plateau, China. These family groups' territories consist of a traditional communal burrow system on which adult males and females live and their young of the year. Approximately 25 meters separates the center of activity of a family group from that of each of the surrounding family groups. Regional density may approximate 300/ha following the reproductive season, although density at this time is highly variable among years (Huntly et al., 1986; Smith and Gao, 1991; Dobson et al., 1998). American pikas (*Ochotona princeps*) live at low density, but they are long-lived, some individuals live six years (Smith, 1978). *O. hyperborea* held territories of 900m², used the same shelter, spent most of their time in the same core area and stores food collectively. Males and females differed in mobility, and behaviour related to defense of territory (Gliwicz et al., 2006). These behaviours and phenomenon were not observed in pikas of Langtang.

Kawamichi (1968) explain about syanthropic tendency of *O. roylei* in Gosainkunda area and at Dewche village, they live within native houses, walls of which were made by a heap of rocks. They run through the interspaces of walls and their excrement is found on shelves in the sitting-room (Kawamichi, 1971b). Such trait was not observed in *O. macrotis* at Pheriche village in Sagarmatha National Park (Kawamichi, 1985). Bhattacharya et al., (2009), Koju and Chalise (2013) also explained that pikas lives near human habitat and sometime visit and live inside the wall of the home and shed made by people. In Langtang National Park Royle's pika, most often visit to human settlement and even collect food from the home during winter, but this phenomenon was not observed in *O. macrotis* and forest dweller *O. roylei*. These results support the previous study by Kawamichi (1968 and 1971).

Pikas in Langtang were not observed below 3005 masl in the study period. There were only two species of pika in Langtang National Park. Both species were sympatric in habitat but only *O. roylei* inhabit in forest area. They were comparatively dark in colour than other habitats. There population density of pikas (including both species) is highest in subalpine area (12.3/ha) then in alpine area (9.16/ha) and least in forest area (4/ha). Only *O. roylei* visit human settlement. The pikas in Langtang had no any territorial behaviours and do not live in family like other pikas in Tibetan Plateau.

4.7.2. Home range and territory

The home range is depend on the body size and weight of an animal (Swihart et al., 1988). Kawamichi (1968) explained the home range for *O. roylei* in Gosainkunda was 1000 m^2 to 1350 m^2. Pikas sometime travel inside forest and bushes near to this home range but they were not seen more than 10 m deep inside the forest or bush (Kawamichi, 1968; Smith et al., 1990). (Kawamichi, 1969; 1971b) used the term nest range for the home range during the research of Japanese pika and American pika. In Khumbu area, Nepal, the fixed nest range for both species of pika was not found (Kawamichi, 1971b). Different individual population overlapped nest ranges and behaviour of territorial defense was not recorded. In current research, we found the maximum area used by single pika was within 50m × 50m but other individuals overlapped this area too. Pikas were notices chasing and pseudo fighting each other but no territorial defense was recorded. Khanal and Shrestha (2000); Khanal (2007); Bhattacharya et al., (2009); Joshi (2009); Koju et al., (2012b); Koju and Chalise (2013) had not explain about the territorial behaviour of the pikas in their research works from different parts of Nepal and India. Kawamichi (1982) calculated the home range of *Ochotona hyperborea* by using 5m grid system and explained the home range was affected by sex, age, dominance rank and size of rock in that area. Gliwicz et al., (2005) reported that the home range of *O. hyperborea* by observation of 14 pikas is spatial behaviour as 900 m^2. During the research on *Ochotona princeps,* Smith and Ivins (1984) recorded about 95% no chase in all instances when two pikas encounter each other. They used the term "social tolerance" for that situation between nearest neighbors and opposite gender. Kawamichi (1985) explained that *O. roylei* from both central Nepal and Khumbu region does not show any territorial behaviour but *O. macrotis* in Khumbu does it. He further clarified that it was not significant and specific as in *O. princeps*, *O. hyperborea* and *O. collaris* in comparatively.

In *Ochotona princeps*, the home ranges of resident adult males and females were of equal size on talus, the obligate habitat of pikas. Adjacent home ranges were normally occupied by members of the opposite sex, and this spacing apparently results from the balance of agonistic and affiliative behaviours exhibited by nearest neighbor heterosexual pairs (Ivins and Smith, 1983). But Barash (1973) explained that American pikas defend most of their home range, except during the mating season, when male territories expand to overlap with females. In the haying season territories, become more exclusive and more energetically defended. Home ranges of this species include 0.3-0.5 ha (Barash, 1973) and 0.26 ha, varying from 0.04-0.30 ha (0.1-0.75 ac) in Rockies of USA (Kawamichi, 1976).

The territorial behaviour and defending its home range may be very closely related with haying behaviour of pika. Haying behaviour is very poor in pikas of Langtang so there may be absence of territorial behaviour too. In this research, chasing were observed less than 1% of their total external time budget and most of the chasing were observed in juveniles, which seems like rough playing among them or pseudo-fighting expression.

4.7.3 Colouration in pika

Lagomorphs' pelage colouration matched to habitat type, geographical region, altitude and their behaviour. The basic body colouration of most lagomorphs consists of an overall grey or brownish body hue that lightens ventrally (Stoner et al., 2003). General body colour resemblance to its surroundings situations in which an animal's inhabits (Kiltie, 1989). Variable colour pattern in mammals' resemble its colour alter with its changing surroundings. In some mammals, this colour change phenomenon occurs seasonally. Colouration may also play a role in communication (Holley, 1993). Pelage colour shows geographic variation of animal too (Howell, 1924). The pelage colour closely matches the colour of the rocks where the pikas live. There is probably a strong selective force for cryptic colouration due to predation by birds (Broadbooks, 1965).

The pelage colouration in *Ochotona macrotis* and *Ochotona roylei* were studied by Kawamichi (1968), Abe (1971), Kawamichi (1971b), Smith and Xie (2008) and Koju et al., (2012c). Kawamichi (1968) recorded that in summer at Gosainkunda area the head, shoulders and fore part of the body of *Ochotona roylei* is bright chestnut coloured, becoming more vinaceous on the throat. The remainder of the dorsal surface is dark grayish rufous. Ventrally, the colouration ranges from white to grayish white to dark gray. The winter coat is similar, but may show only traces of or lack of rufous colouration. Most specimens of *Ochotona roylei* examined from central Nepal by Abe (1971) had similar winter fur except for the facial parts in which new rufous summer fur was coming up. He explained adult males have a wide chestnut colour band on the throat.

Grayish colouration of *O. macrotis* seems effective for their protection at the sunny grayish slide rocks habitat at least for the human beings, as well as rufous colour of *O. roylei* and *O. hyperborea yesoensis* for dusky ones, irrespective of the mechanism underlying the development of colouration (Kawamichi, 1971b; Smith and Xie, 2008). They explained the general colour above is pale brownish gray with an ochre tinge. Along the sides of the face, across the shoulders and from the nose over the occiput, the general grayish colour is tinged with rufous, which is more marked during summer. In winter, the dorsal colour changes to a dense fluffy pale gray with a tinge of straw yellow. The belly ranges from white to dull dirty white in summer and winter. The head and front are washed with a pale russet colour instead of the brilliant rufous brown in Royle's pika.

Kawamichi (1971a) explained that Northern pika (*Ochotona hyperborea*) changes pelage twice a year, at spring and autumn. Winter pelage after autumn moulting is denser than summer one. The colour at back is generally dark brown as compared with reddish brown in summer, though the difference is not so distinct and a minor colour variation is observed among individuals. The pelage colouration observed in current study is similar as explained by previous researchers. However, during present study the different colouration was observed in juvenile pika near Suryakunda area. It was grayish white with black colour tip of limbs and white lining in eyes and ears. Such variation and distinct colouration change seems to be first report from Nepal on pika species. Kawamichi (1971a) stated the colouration pattern in *O. macrotis* is more or less similar to Northern pika (*O. hyperborea*).

4.7.4 Behaviour

4.7.4.1 Calling

The name pika derived from mimic of 'peeka' the calling of pika (Macdonald, 2001). Calling is the peculiar character of pika (Smith et al., 1990). Royle's pika in Gosainkunda were not observed making sharp and loud call (Kawamichi, 1968). Abe (1971) heard just two calls at Thadepati in his study period. Pikas in Sagarmatha (Mt Everest) region were not observed and heard making call (Kawamichi, 1971b). Calling of pika in Api Nampa was short and poor too (Koju and Chalise, 2013). In current study, some calls of pika in summer season were recorded and was less than 1% of total external behaviour. Two types of calling was recorded during summer: long call surrounding Chirrr…rrr and short call 'chi chi. However, in winter just a single call was heard in total 9900 minutes of observation.

Ochotona hyperborea yesoensis (Japanese pika) in Japan makes frequent high calls (Kawamichi, 1969; 1985; Kojima et al., 2006). The call of this species was also loud and sharp than, it can be heard from 200m far (Kawamichi, 1969). Their high calls were frequently responded by neighboring pika (Sakagami et al., 1956). Therefore, calls in pika were regarded as way of communication among themselves. American pika (*Ochotona princeps*) also makes sharp strong and frequent calls. Both male and females were observed making call (Smith, 1981; Conner, 1983; Ivins and Smith, 1983; Kawamichi, 1985; Smith, 2004; Hoffmann and Smith, 2005; Wolf et al., 2007). Vocalization and olfaction in *Ochotona princeps* were proposed as means to modify aggressive behaviour through sexual and individual recognition (Barash, 1973). Calling is not only communication in intra-species but also information to predators; call brings predators closer to them than animals who do not call. Pikas may increase their chances of being preyed upon by calling (Somers, 1973; Conner, 1983). Therefore, the poor calling in pikas of Nepal especially in Royle's pika (O*chotona roylei)* and larged ear pika (*O. macrotis)* of Langtang National Park may the adaptation during evolution to avoid predator pressure. Pikas are major food of himalayan big predator mammal and Himalaya bears other many predator species of pika (Oli et al., 1993; Jackson, 1996).

4.7.4.2 Food hoarding

Food hoarding or constructing hay pile is another special character of pika to escape or avoid the inaccessibility of food in harsh season of the year from starvation. It is one of the adaptations for supply of winter food when habitat is usually covered by snow. In Khumbu, Sagarmatha (Mt. Everest) region food hoarding was never observed during winter by *Ochotona macrotis* and *O. roylei*. A single exception was a small hoard consisting of 14 plant pieces probably of *O. macrotis* found on 27th December, 1971 (Kawamichi, 1971b; a). In Api Nampa area Koju and Chalise (2013) reported observation of a single old hay pile with old pellets in 2012 which consists of five species of forage plants, two were from Poaecae family, *Fragaria* species, *Potentilla* species and *Rumex* species. The hay pile materials were very dry and de-structured so further detail could not reveal. There was not any hay pile recorded in same season of successive year (Koju and Chalise, 2013). Khanal and Shrestha (2000) did not report about presence of hay pile in Langtang but Khanal et al., (1999) reported 33 species of plants deposited in hay pile of Royle's pika among 48 species of plants found around their home range in Bajura, mid-western region of Nepal. Abundance of Royle's pika of Uttarakhanda, Bhattacharya et al. (2009) reported very low hoarding capacity of pika. The scarcity or virtual absence of hoarding behaviour in *O. macrotis* and *O. roylei* is noteworthy (Kawamichi, 1971b). Similar report on absence of hoarding behaviour observed by Bernstein (1970) on *O. macrotis* of Tien-Shan Mountains, China.

Ochotona hyperborea yesoensis in northern Japan starts hoarding food for winter from late July to October and American pika (*Ochotona princeps*) start a month early - June to October (Kawamichi, 1985). *Ochotona princeps* spends a considerable amount of time during summer caching vegetation. These caches (hay piles) have been suggested to function as diet in winter and source of food for intermittent periods when the animal is unable to forage elsewhere, or in nonfood functions, e.g., nest sites (Dearing, 1997). *O. princeps* are asocial (Morrison, 2006) does not cooperate to build other's hay pile. They were observed making up to 13 trips/hr for haying (Beever et al., 2003).

Travina (1984) calculated that even at a modest density of ten to twelve pikas per ha, storage amount of vegetation by pikas may up to 30 kg/ha in Afghan pika (*Ochotona rufescens*). The stores of an Afghan pika may contain up to 58 species of plants and weigh to 5 kg (Sapargeldyev, 1987) remain exposed above the surface of the snow. Daurian pika (*Ochotona dauurica*) accumulate hay pile at the entrance (Kawamichi and Dawanyam, 1997) which they use mostly in breeding season for breeding purpose and also used as food in winter. *Ochotona curzoniae*, ecologically similar species to *O. dauurica* also store hay pile in its burrow which is most often used by different birds and mammals as source of insulation in winter and simultaneously used for food by pika (Smith and Foggin, 1999; Lai and Smith, 2003).

Dearing (1996) recorded that *Ochotona princeps* hording selection depend on morphology of plants. They prefer large size plants species for hay pile. Leaf morphology and size effect in selection of food was also explained by Bhattacharyya et al., (2013) in his research of *Ochotona roylei*. Elliott (1980) explored eleven hay piles of a pika (*Ochotona princeps*) colony in central Idaho, USA and found 26 species of plants in the hay piles. Aho et al. (1998) had explained pikas as allogenic engineer of alpine ecosystem. Their team found that hay pile soils had significantly higher carbon and nitrogen levels and lower C/N ratios than both adjacent soils and soils in the general study area. Su et al., (2003) had explained on behaviour of hoarding hay pile by Gansu pika (*Ochotona cansus*) in Gansu China, observing 27 hay piles in late fall of the year from meadow. In the Chelyk-Khem River valley, Travina et al., (2000) explained that Altai pikas begin to store plants between July 10 and October 21, a week earlier than northern pikas. A family of pikas in that place usually makes two to seven stores (stacklets) located 1-3 meters apart from one another in the same places from year to year. Broadbooks (1965) explained that *Ochotona collaris* from Washington State, USA are very active in hoarding hay pile and they stored 40% of plants species available in their habitat. Field observations of Holmes (1991) made on *Ochotona collaris*, in Alaska determined that these pika do hoarding food even though high risk of predation during foraging, they do not travel more than 10m for forage. Similar findings were explained by Morrison et al., (2004), which explained that due to predation risk, *Ochotona collaris* store poor quality food for winter.

In current research, both species of pikas in Langtang area were not active in storing hay pile. Only seven hay piles were observed during winter season with dry vegetation of *Argemone* species, *Artemisia vulgare, Fragaria* species, *Gramineae* species *Juncus thomosnii, Ligularia ampllexicaulis, Poa* species and some very dry unidentified plant species. In summer, Royle's pika at forest and its edge area were never observed carrying forage. In subalpine area with broken rocks habitat pika species was observed twice, *Ochotona roylei* was found transferring and hoarding forage for nine times, but the consumption time of this foraged was not known. Thus, there is very weak food hoarding nature of O*chotona macrotis* and *Ochotona roylei* in Langtang. It may be because of presence of dry vegetation during winter or they adapt to feed on dry plants and shrubs or tree bark. The foraging behaviour and haying nature of those two species as well as other species of pikas in Nepal is still unexplored in detail.

4.7.4.3 Musing

Pika use to stay motionless a few seconds to several minutes on the rocky open place. Such behaviour of sitting is called as musing. Kawamichi (1968) reported two types of musing in pikas of Gosainkunda region. For shorter period pika come out of burrow or from gap of rocks pile and sit on the open rocks as if monitoring surrounding. It was termed as brief musing. It occurs during daytime and frequently intervention by other activities. They do auto grooming during this types of musing. Second is prolonged musing which continues for several seconds and minutes with motionless and sometime camouflaging to the surrounding; this appears during down and dusk. He had recorded pika musing up to 15 minutes without making any other particular movement. It was like resting or sleeping posture making body round. All pika species were reported to do musing and the pattern of musing is similar in all cases (Kawamichi, 1969; 1971b; Smith et al., 1990; Hoffmann and Smith, 2005; Koju and Chalise, 2013). Current research reveals the similar general patterns of musing as explained by previous researches. Musing behaviour has the higher time budget during daytime, especially in winter they spent most of their daytime in musing. In both species of pika, musing time budget for daytime is more than 50 % in all seasons. The maximum musing time in one shift was recorded as 22 minutes in *Ochotona roylei* before sunset. Kawamichi (1971b) also recorded the maximum length of musing in

Ochotona macrotis species for 22 minutes in Khumbu, Sagarmatha area. He further explained that musing of *O. roylei* is mostly performed under dim light and *O. macrotis* in day light but this pattern was not observed in Langtang in present study. Two or more than two pikas were observed musing in single large rock or near to each other not far than 2-3 meters which were not reported in other species and research from other area except one example explained by Kawamichi (1969) in *Ochotona hyperborea* from Hokkaido, Japan.

4.7.5 Forage selection of Pika

Pikas are a generalist small herbivore, relying on a wide variety of herbs and grasses (Smith et al., 1990). Forage selection decisions of herbivores are often complex and dynamic; they are modulated by multiple cues, such as quality, accessibility and abundance of forage plants (Bhattacharyya et al., 2013). Daily foraging decisions are constrained by a number of other factors, which may be classified as either internal such as energetic or nutritional needs, or external such as predation risk or inter specific interactions (Lima and Dill, 1990). These constraints limit the availability of food items to the herbivore and explain why most species exhibit some degree of diet selectivity. Most species, therefore, must balance trade-offs associated with these constraints such as obtaining enough food while minimizing predation risk, or decisions about selecting species with differing degrees of nutritional value (Stephens and Krebs, 1986). In KWLS, India 26 plant species were found to be consumed by pikas. The proportion of forage plants was the highest (77.4%) on the rocky slopes of the timberline zone (Bhattacharya et al., 2009). Among them only 17 (total bite count = 3153) were major food plants of pika (Bhattacharyya et al., 2013). The leaf size and quantity of avoided substances (fiber and secondary compounds, such as tannin) was important cues for selecting forage plants (Dearing, 1996).

Dearing (1997) predicts that pikas will select plants with low secondary metabolite contents and pikas prefer forage with low fiber and lignin contents (low NDF, ADF and ADL values). Hudson et al., (2008) identified collared pikas' preference for larger leaves in their winter diet in both field and multiple choice feeding experiments. Dietary fiber constitutes the greatest mass in herbivore diets, but is less digestible than other nutrients (Mertens, 2002). NDF and ADF represent cellulose and hemi-cellulose contents of feed, whereas ADL represents the lignin and cutting contents of plant cells. High fiber content (NDF, ADF and ADL) reduces forage digestibility. Royle's pika preferred forage with low fiber and lignin contents and plants with large leaf areas, low fiber (NDF, ADF and ADL) and low tannin contents (Bhattacharyya et al., 2013). Plants in hay are higher in protein, lipids, and calories, and lower in fiber, than plants not selected (WEST, 1980).

Nitrogen content (in current research we measured as crude protein), the macro nutrient plays an important role in abundance of small mammals (Krebs et al., 2001) as it is the principal constituent of amino acids essential for growth and reproduction. Alpine ecosystems are strongly limited by nitrogen availability (DeLuca et al., 2002), therefore the amount of nitrogen or crude protein in forage plants might have a very large impact on forage selection in alpine herbivores. The American pika was found as the top refer nitrogen rich forage for its winter diet (Millar and Zwickel, 1972a; Dearing, 1996). Calcium, an important mineral nutrient, is also positively correlated with pika forage selection, likely because calcium is essential for maintaining skeletal tissue, trans-mission of nerve impulses and milk production (Bhattacharyya et al., 2013). In present research the most consumed plants contain high moisture contain, high organic matter and calcium value. The amount of nitrogen was less in feeding items in the study area. The moisture contain has significant relation with elevation. Its value decreases with elevation. Similarly, the value of calcium in the forage consumed in all elevation and habitat increases as elevation increased. The result of ADL, NDF and ADF supports previous researches. The evidence of selecting broad or large leaf was not noticed in this study. Most consumed (in frequency) forage contained both small and broad sized leaf plants.

In Langtang National Park, species recorded 65 plants in pika habitat as ground vegetation. Among them 58 were consumed by pika in different habitats. Subalpine area had 52 plants species as ground vegetation and pika consumed 46 plants species of them. It was the highest forage plants number and consumed among all habitats. The value of nutrition like protein, hemi-cellulose, organic matter and minerals such as calcium and potassium were highest in subalpine area too. The comparison between nutrition of plants at different habitats show plants of subalpine area is the most nutritive (in protein, Hemi-cellulose, potassium and calcium). Pikas population abundance show their population density was highest (12.3 individual/ha) in the subalpine area too. This suggest that population distribution of pika had been affected by nutrients presence in foraging plants of that habitat.

Plants like *Rumex nepalensis* was found in two habitats in study area, *Moehringia* species and *Pedicularis megalantha* were found in single habitat in study area. These plants species were consumed by pikas where they were available. These plants were consumed in highest frequency in all respective habitats. Similarly plants like *Geranium nakaoanum*, *Gramineae* species, *Juncus thomosnii* and *Ligularia ampllexicaulis* were consumed in highest frequency in different habitat even they had high NDF, ADF cellulose and hemi-cellulose (less nutritional) value. Pika feed on all ground vegetation (100%) within quadrats in Gosainkunda Lake area. This phenomenon supports the result of primate research in which primate feed according to vegetation distribution and availability. It also indicates that special plants or species or families are not under the preferences of diet (Chalise, 1999).

The pikas excreted both hard and soft fecal matter with virtually complete consumption of the soft type (Smith et al., 1990; Hoffmann and Smith, 2005). Matsuzawa et al., (1981) explained that the hard fecal of the pikas were 2-4 mm in diameter, 17-19 mg in weight, and greenish-ochre in colour. 40-70 of these hard fecal pellets were excreted at one time, the number per day being 8.6 times that of the rat and 4.2 times that of the guinea pig. Severaid (1956) reported that Pikas are coprophagous like other lagomorphs. They produce two types of feces, one of which is re-ingested, thus increasing the efficiency of nutrient extraction (Johnsond and Maxell, 1996). Present study supports the previous researches on pellet characters and coprophagous nature of pikas. The number of pellets was less (10-12) than the number of *Ochotona princeps* (40-70) explained by Severaid (1956).

During present study period, pikas were observed feeding on cow dung (Thadepati). Pikas in Laurebina also found drinking water by licking it on rock and licking minerals and soil were recorded. These behaviours were not explained in other researches and seem new records for the pika feeding behaviour. Water and extra minerals intake are the common phenomenon herbivore in general.

Social behaviour of pika was explained for the species of *Ochotona curzoniae* and *O. dauurica* (Smith et al., 1990; Hoffmann and Smith, 2005). They explained about living in-group on these species as well as seasonal monogamy. During present study, partial parental care was observed but it needs more specific observation with quantifying data. During seasonal observation of *Ochotona princeps* Conner (1983) found the young pikas became surface active in August. In *Ochotona roylei* and *Ochotona macrotis,* this phenomenon was observed from the last days of June. After heavy rainfall (monsoon) in June, pikas were very active in feeding and foraging and their juveniles were seen in external activities too at this time. This was also little different with elevation in Langtang. At higher elevation, Juveniles were observed from mid of July only. The initiation of external activities in Nepal's pika was earlier than American Pikas. The major factor for this may be different in weather pattern and elevation gradients. Conner (1983) further explained that individuals still show highly territorial (as indicated by chases, agonistic encounters, and calling) activity and there was a second reversal in the relative amount of time spent feeding and haying in October. In November, the proportion of time spent feeding was significantly less than the proportion of time spent perching (t, = 7.46, $P < 0.001$). Pikas were not seen on the surface from February through May in the Niwot Ridge population. The first individual seen on Niwot Ridge, Colorado, USA was on second week of June. During present research in Nepal, we also notice relative less activities of pika after November and encountered very few pikas in winter. No juveniles were observed in winter. But Kawamichi (1968) recorded 14.2 individual/ha in same study area, this numbers is more than the pika density recorded in summer in this study thus we can conclude either of the highly decrease in population and external activities of pika in winter or data collection is uncertain.

Kawamichi (1971a) explain presence of orange coloured mites in captured specimens of *Ochotona hyperborea*. He further explains a weasel (*Mustela* species) and yellow-throated marten (*Martes flavigula*) regularly invade the burrow of pika. During this research, grooming was observed a prominent behaviour among pikas but was unsuccessful to collect or observed any ecto-parasites, lice, or flea in captured pikas. Observations of frequent weasel visit to pika's burrow in Gosainkunda Lake premise were recorded frequently, however, never observed killing pika by any visitor. However, local people reported killing and feeding of pika by weasel species.

4.7.6 Pika and Climate

Many taxa response to inter-annual fluctuations in precipitation, temperature and extreme climatic events over ecological and evolutionary timescales (Post and Forchhammer, 2002). The abundance, distribution, and demography of animals are known to track climate-related variables over a broad range of spatial and temporal scales (Post and Stenseth, 1999). The warming of global climate is now unequivocal. It is given that global temperature could rise as much as 6.4°C by the end of the twenty first century (IPCC, 2007). Climate change is one of the most significant contemporary threats to biodiversity worldwide and is expected to have a profound effect on both individuals and population in animal communities (Isaac, 2009).

While the Earth has experience much variability over historical time, current climatic changes differ in two important ways in terms of their negative impact on biodiversity and extinction rates. First is the rate of change is generally considered to be unparalleled with the past 10,000 years. At the same time, extreme high temperature and rainfall events will also become more common, while snow cover and sea ice will decrease and contribute to rising sea levels. Second is many of the Earth's ecosystems are already stressed by human impacts, such as land clearing and habitat fragmentation, making small and isolated populations highly susceptible to the type of stochastic events which climate change will bring, such as wildfires and hurricanes (IPCC, 2007).

Biological events is related to air temperature, soil temperature, precipitation, soil moisture, snow cover, solar illumination and photoperiod (Green et al., 2008). Biotic responses to climate change will vary among taxa and across latitudes, elevation gradients, and degrees of insularity (Beever et al., 2010). The past changes in fauna and migration pattern provide useful information for predicting the changes that present animals. When their environment becomes warmer or colder, the biotic community is forced to migrate (Kawamichi, 1998). However, due to factors such as phenotypic plasticity, ecotype variation, and evolved tolerance to thermal stress, it remains poorly understood whether losses should be greatest in populations experiencing the greatest climatic change or living in places where the prevailing climate is closest to the edge of the species' bioclimatic envelope (Beever et al., 2010; Beever et al., 2011).

Fossils of pika provide an excellent indicator of the climate change of the past (Kawamichi, 1998). Living pikas are adapted to cold climates that characterize higher altitude and higher latitude. Throughout the Pleistocene (1.6 million to 10,000 years ago), glacial have alternated with inter glacial over a cycle lasting about 100,000 years. The climate alternately grew colder and warmer, and the change it brought had a major influence on the evolution and migration of life (Kawamichi, 1998). Ochotonids first appeared in mid-Oligocene (30 million year ago) in Asia and Europe (Dawson, 1967). During the Miocene (23.3-5.2 million year ago) there were 13 genera of family Ochotonidae ranging from Eurasia to North America and Africa.

In Pliocene (5.2 to 1.6 million years ago), pika diminished to four genera. The present genera *Ochotona* first appeared in Pliocene and rest three genera of that period were extinct (Kawamichi, 1998). The Indian sub-continent collided with Tibetan platue to form Himalayas in Miocene. This incident opened up large area to cold climate. It is supposed that modern pikas were the descendant of ochotonids that moves into these cold regions. Other genera which lived in warmer climates may ultimately unsuccessful (Kawamichi, 1994).

Pikas have not changed much in term of morphology and behaviour however, and consequently, many pikas fossils from the late Pleistocene are included as members of same species that exist today. This is because their skull form has been extremely "conventional", making it possible to work out the range that today's pika species occupied in the past (Kawamichi, 1998). The steppe pika (*O. pusilla*) ranges throughout Europe during the late Pleistocene, but after the late glacial, gradually retreated from the west to Kazakhstan (Smith et al., 1990). The Mongolian Pallas pika (*O. pallasi*) has steadily decreased in number in Gobi desert during last few thousand years. The bones of *O. pallasi* accounted for 23.6% of all the excavated bones of small mammals deposited 3000 to 4000 years ago, but this percentage decreased to 7.3% for period of 1500 to 2000 years ago and just 0.4% of bones deposited over the past 200 years (Smith et al., 1990; Kawamichi, 1998). Owl pellets in Gobi desert revealed the same conclusion. Owl fed on pika as prey species. Owl discharged undigested bone through mouth called owl pellet. Owl pellets contained bones of pikas. Bones of *O. pallasi* accounted for 38% of pellets from 1100 years ago, falling to 21% from 600 years ago (Smith et al., 1990). Stanislav et al., (2006) reported the new records of *Ochotona* from Iran and Turkey. The findings of the bone remains from the Eagle owl pellet in Turkey represent the first record of the genus to this country. They found fossils of Afghan pika (*O. rufescens*) from seven different places of Iran and Turkey. These fossils support the presence of pika in Middle East Asia in past. Change in climate pattern and temperature extinct the pika in this region.

During the late Pleistocene, a large form of *Ochotona*, known as *O. whartoni* were extinct from the Western Arctic. It was found as far east as Ontario, Canada as late as 9000 years ago. It was believed that a smaller form of *O. princeps*, lived in the eastern United States until sometime during the last glaciations (Mead and Grady, 1996). The restriction of American pikas to rocky settings also seems recent. Analyses of pika remains from ancient wood rat (*Neotoma floridana*) in western North America shows that at 12,000 years ago, pikas were living at relatively low elevations (< 2000 m) in areas devoid of talus (Rhode and Madsen, 1995). The rapid eco-regional range shift of this small, talus dwelling species stands in remarkable contrast with other previously observed for most terrestrial species and it leads to earlier extinction determinants for *O. princeps* in this region (Beever et al., 2011).

The seven (28%) of the 25 historically described populations of American pikas (*Ochotona princeps*) in the Great Basin of western North America appear to be extinct (Beever et al., 2003; Beever et al., 2010). McDonald and Brown (1992) and Beever et al. (2003) had added emphasis to earlier warnings that Great Basin populations of this animal are highly vulnerable to climate change. The Multi-model means of surface warming (relative to 1980-1999) scenarios of Sierra Nevada and Cascades, California, USA show the continuations of the 20th century simulation.

The archaeological and paleontological records for pikas in the Great Basin provide strong support for this view of Great Basin pika history, documenting their Pleistocene and Holocene presence on mountains and in valleys where they no longer exist. This record also suggests that prehistoric pika extinctions were driven by increasing temperatures, decreasing effective moisture and attendant changes in plant communities (Grayson, 2005). The American pika became extinct in the lower elevations of the northern half of the Great Basin about 7,000 years ago. Scientists believe that during this period of history the Great Basin saw an increase in summer temperatures and precipitation and a decrease in winter precipitation (Grayson, 1987). Research on American pikas (*Ochotona princeps*) in the Great Basin during 1994–1999 suggested that 20th century population extirpations were predicted by a combination of biogeography, and especially climatic factors (Beever et al., 2010).

Grinnell (1917) was the first researcher to observe early a relationship between elevation distribution and temperature limitations of pikas in the Sierra Nevada, as the species are limited to high elevations because of cold temperatures(Fig 58). Beever et al. (2011)found that climate became the dominant factor for extirpation of pikas. The colonies of pikas disappeared from entire sites of Great Basin USA, once every 10.7 years during the 20th century. Since 1999, their extinction rate jumped to once every 2.2 years. Pikas also migrated nearly 475 feet up-slope in the past decade, an 11-fold leap over the roughly 40-feet-per-decade shift seen throughout the 20th century (Beever et al., 2010).

Populations of pika in the Great Basin of western North America have been lost from a number of sites, during both prehistoric (Grayson, 2005) and historical periods. Several lines of evidence suggest that 20th century losses were tied to thermal stress (Beever et al., 2003). Pikas were lost from hotter and drier sites at higher elevation, from sites at lower elevation, and especially from sites lacking a thermal refuge (Beever et al., 2010). Since 1999, four out of ten pika have been in extirpation, and across this Great Basin eco-region of the low-elevation range boundary for this species is now moving upslope at an average rate of about 145m per decade (Beever et al., 2003). They conducted the research using several alternatives which are not mutually exclusive, their higher probability were correlated with higher area of talus habitat, higher elevation, different latitude, lack of livestock grazing, maximum wilderness but the result suggest that population loss can occur with no apparent change in habitat.

In another research Beever et al., (2010) found American pikas (*Ochotona princeps*) in the Great Basin during 1994–1999 suggested that 20th century population extirpations were predicted by especially climatic factors combination with bio-geographic and anthropogenic. To evaluate this evidence in support of alternative hypotheses they placed temperature sensors at 156 locations within pika habitats in 25 sites where pikas were located with historical records. Their results illustrate that extremely rapid distributional shifts explained by climatic influences (Beever et al., 2010). Haga (1960) explained the sensitivity of *Ochotona hyperborea* to pneumonia and spergilosis when they are kept in lowland condition.

It is assumed that chronic-heat stress affect by climate change is more than acute-heat stress, because minimum temperatures have risen two to three times more than have maximum temperatures during the 20th Century (Karl et al., 1993). Acute-cold stress may be important where snow cover does not insulate pikas during cold periods.

MacArthur and Wang (1973) explain that experimental research has shown that pikas are particularly vulnerable to acute heat stress. They assumed the acute heat stress was the number of days in which the maximum temperature was above 28^{0}C. As pikas do not hibernate, lack of snow means lack of insulation from harshly cold winter temperatures. Given that mountain snowpack has been declining (Mote et al., 2005). Regarding acute heat stress and cold stress, Beever et al. (2010) explained that above 20^{0}C is acute heat stress and below -5^{0}C is acute cold stress to pika survival. They further suggested that pika extinct from those places, which have more days with minimum temperature less than -5^{0}C. During present research, it shows that the minimum temperature is increasing especially in winter. The rainfall in winter season of Langtang was also in decreasing pattern even though it is not significantly decreased the slope equation ($y = -.02789x+15.562$) had negative value. This phenomenon leads to decrease snowfall as well as the snow pack in pika habitat area, which decreases insulation effect. The maximum temperature has no significant change since 1987 but minimum temperature shows increased.

The temperature recorded by iButtons in pikas' burrows show that maximum temperature at 3980masl and 4600 masl was higher than lower elevation in both seasons. The average maximum ambient temperature and temperature inside burrow was similar (5.47^0C) in winter (see Table 22 and Table 23). The mean minimum temperature inside burrow was below -5^0C but the ambient average minimum temperature was higher (-2.3^0C). This pattern of temperature supports the insulation effect of snow. The temperature inside the burrow was decreasing and the number of days with temperature $> -5^0$C is increasing especially in January and February (cold season). This was causing acute cold stress to pikas during winter, which may be major cause of pikas extirpation locally in Langtang National Park as explained by Beever et al., (2010) in Montane, Colourado of USA.

So pika is facing climate change and their population is affecting not by increasing heat in summer but increasing minimum temperature in winter that melt the snowpack and reduce insulation effect. So on the basis of present research it can be suggested that pika are under threat of thermal stress not because of heat or increase in temperature but due to acute cold caused by increasing in minimum temperature in Nepal Himalaya.

Barry (1990) explained Himalayan ecosystems are sensitive to climate change. So pika can be considered as indicators of climate change (Beniston, 1994). Higuchi et al. (1980) explain that the glacier of Himalayan region have retreated in two decades. Li and M. Tang (1986) explained changes in air temperature from 1950 to 1970 of Qinghai- Xizang (Tibetan) Plateau showed a decreasing trend and an increase after 1970. Climatic changes in the Himalayan region could be a reflection of large-scale climate changes. The Himalaya and Tibetan Plateau is main region of monsoon circulation that play an important role in regional climate (Dey and Bhanu Kumar, 1982). Hingane et al. (1985) explained that long-term study indicates an increase in mean annual temperature of 0.48^0C over the past century. International Center for Integrated Mountain Development (ICIMOD, 2007) has reported that warming in Nepal has increased progressively within a range of 0.2-0.6°C per decade from 1951 and 2001 (Fig 58).

Temperature records from the mid-1970s from 49 stations of different parts of Nepal reflects the average temperature between 1977 and 1994 increased at a rate of 0.06^{o}C per year; the rise in temperature was greater at the higher elevation (Shrestha et al., 1999). The temperature pattern in Langtang supports these previous researches. The warming impact in Himalaya is more than in Tarai region. The annual increasing temperature is 0.04^{o}C, 0.04^{0}C, 0.08^{o}C and 0.12^{o}C in Tarai Plain region, Siwalik, Himalaya and Trans-Himalaya respectively. Thirty years data shows that the temperature increasing pattern is more in trans Himalaya than plain region (Shrestha and Aryal, 2011).

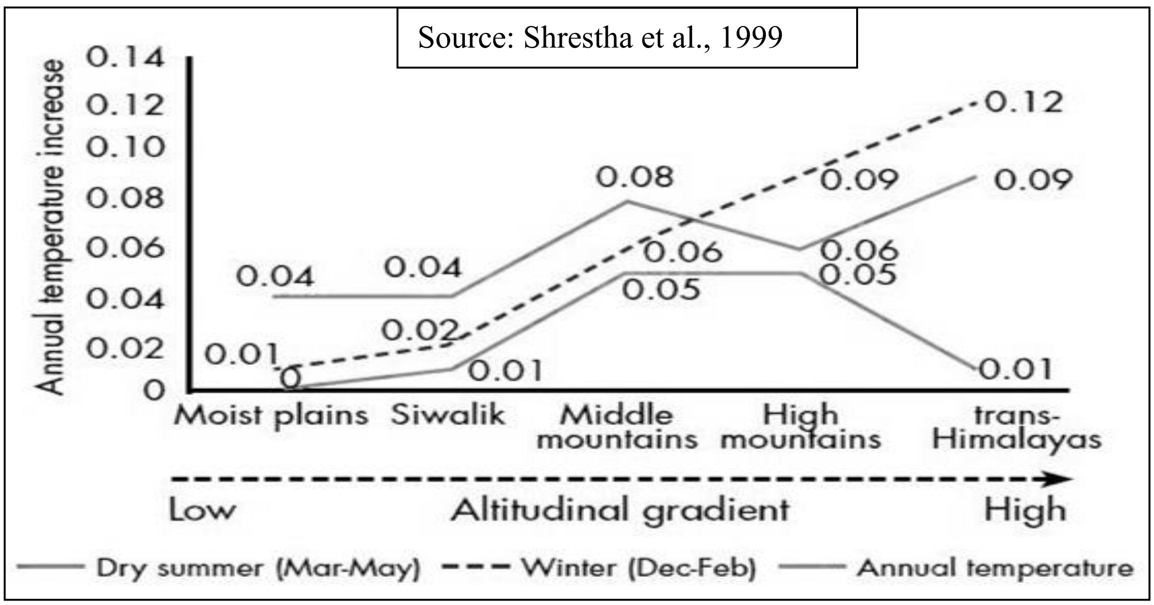


Figure 58: The change in temperature from HKH region between 1970 and 2000 along altitudinal gradient.

The effects of climate change in mountains are claimed to be more intense and detectable since climatic conditions vary more sharply with elevation than with latitude e.g. mean temperatures decline about 1°C per 160m of elevation, compared to 1°C per 150 km by latitude (ICIMOD, 2007). Spatial distributions of maximum temperature trends in Himalaya shows high warming trends in most of the Himalayan region and the Middle Mountains, while low warming or even cooling trends are observed in most of the Tarai and the Siwalik regions (Shrestha et al., 1999). The winter temperature in high mountains and Trans-Himalaya was increasing more than low land of Nepal. It is expected that the average temperature of Nepal in 2030 will be comparatively 1.4 degree centigrade more than in 1977-1999 (Dixit, 2010). It has been estimated that increase of temperature by 1.5^{0}C to 2.5^{0}C will lead to a disappearance of 20% to 30% species sharing this globe (Poudel and Upadhaya, 2010). Study from highland districts of Nepal such as Manang and Mustang has reported declining production of grass in pastures due to moisture deficiencies resulting from reduced snow deposits (Deo et al., 2008).

Results suggest that pika in Langtang is facing either local extinction at lower elevation or they are migrating upward. The lowest elevation of evidence of presence of pika during this research was 3005 masl in Langtang National Park but it was 2100masl by Abe (1971), 2800 masl by Kawamichi (1968) and 2900 masl (Khanal and Shrestha, 2000). Deo et al. (2008) suggested that pika in Langtang migrated upward by 100m. The cause of this shifting or local extinction of pika is supported theory of acute cold stress to pika. The increasing phenomenon in minimum temperature and decreasing snowfall in winter season is major climatic threat to survival of pika in Langtang. Therefore, pika population distribution and its habitat must have some alteration, however very sharp and acute impact due to climate change on pika is yet to wait some years.

Population density of pikas was highest (12.3 individual/ha) at the elevation range of 3000 masl to 3600 masl (subalpine area). The foraging plants in this habitat had the maximum nutritional value like in protein and minerals like calcium and potassium was highest in this habitat among same species of plants and different species of plants. The temperature pattern shows the maximum temperature (inside burrow) in this elevation was warmer in both winter (13.34^{0}C) and summer season (15.2^{0}C). The minimum temperature in this habitat was 10^{0}C to 12^{0}C in summer and 2.3^{0}C in winter. This all phenomenon shows subalpine area with broken rocks was most favorable habitat for pikas in Langtang national Park. The change in temperature was one of the factor affecting population distribution of pika but the nutrition and available of food and forage plants effect the distribution of pikas.

CHAPTER 5

5. CONCLUSION AND RECOMMENDATIONS

Pikas (*Ochotona*) in Langtang National Park are small mammals inhabits in higher elevation forest and its edge to alpine talus area. There are two species of pika in Langtang National Park; they are *Ochotona macrotis* and *Ochotona roylei*. The body length of *Ochotona macrotis* was 14mm (average) more than *O. roylei*. The length of ear and whisker is also longer in *O. macrotis*. *O. roylei* were observed in all habitat but *O. macrotis* was absent in forest and its edge area. They are active in dawn and dusk. Pika in Langtang is locally known as Bhragomjin as respect as Buddhist monk by local people. Total 674 pikas (8.98 individual per ha) were observed in six field works. The population density of *Ochotona roylei* was 4.8 individual per ha in forest and its edge area, 12.13/ha in subalpine area and 7.86/ha in alpine talus area. The *Ochotona macrotis* had no record in forest and its edge but the population density was 8.8/ha in subalpine area and 10.47/ha in talus alpine area respectively. General behaviours like grooming, musing, calling, feeding, foraging, chasing, resting inside burrow and galloping, and some special behaviours like mate (mounting), drinking water, defection of pellets, parental care were observed in different season. Pikas consumed 76 species of plants from forest and its edge habitat to alpine talus. Consumption ratio of available forage plants increase along altitudinal gradient. It consumed 71.73% (33 species) of total available plants in forest and its edge, 88.46% (46 species) in subalpine area with broken rocks, 85.1% (40 species) in alpine and talus area and 100% (27 species of ground vegetation) in Gosainkunda premises. There was no significance in nutrients contain of plants and its altitudinal distribution but the value of total ash and calcium contain of the most consumed forage plant (*Gramineae* species) was significantly increased along altitude.

Pollution is threat for survival of pikas and their external activities in Gosainkunda Lake premises. The meteorological data obtained from DHM from 1987 to 2012, and temperature records from iButtons do not support climate change in Langtang National Park but there is high fluctuation and variation of temperature and precipitation. The value of mean minimum is increasing significantly. The temperature inside the burrows from

3300 masl to 3600 masl was cooler in hot summer and warmer in cold winter, which is favorable for pika survival.

There is no any evidence of presence of pikas below 3000 masl in the study area. It was reported from 2800 masl a decade ago by other researchers; the 200m change in elevation suggests that pikas in Langtang National Parks either locally extinct or upward migrated. The number of days with temperature less than -5^{0}C is increasing in winter that affects acute cold stress to pikas; which may be possible cause of declining population density of pika in Himalayas of Nepal.

Current study focused on diversity, behaviours and climate change vulnerability of pikas at Langtang National Park. We explored existence of two species of pika in LNP, Nepal by the study of habitat and comparative morphology. The *O. roylei* and *O. macrotis* have very similar feature. There was no high degree variation in colour, size and behaviour. They inhabit sympatric in the study areas. Therefore, phylogenetic study is necessary to explore diversity of pikas to its species and sub species level.

Anthropogenic pollution in pika habitat is very common and increasing in Langtang National Park. Pollution is affecting negatively free movement of pikas and degrading quality of their habitat. Therefore, action against pollution should be taken as soon as possible by responsible organizations for conservation of pika species including to others.

Deep rivers, high mountains and gullies separate the habitat of pikas in Langtang National Park. Pikas do not travel long distance similarly; they cannot cross deep rivers and high mountains. Such geographical features play vital role in speciation and distribution of pikas; so study on biogeography of pika is very important to explore its evolution and distribution. Pikas in Langtang National Park observed very less in calling behaviour and their activities on food hoarding for winter seems scare. It seems the special ecological adaptation of pikas of Nepal. The reason is still unknown so, adaptation and eco-physiology of pika should be studied.

Nepal is known as rich country in biological diversity. It is assumed the Himalaya of Nepal has five different species of pikas but we do not have collection of voucher specimens of pikas (except single museum specimen of *O. roylei* in Natural History Museum, TU from Langtang region) from different habitat and different species. It is very important for comparative morphological study. Therefore, voucher specimens of all species of pikas and their sub species found in Nepal should be collected in University museum.

Pikas do not hibernate even in harsh cold temperature. They store food for winter, obscure climate. The habitats of pikas are also the habitat of big herbivore like yak (*Bos mutus*), blue sheep (*Pseudois nayaur*), Himalayan tahr (*Hemitragus jemlahicus*) and musk deer (*Moschus chrysogaster*). Therefore, detail study of food selection and use by pika will be useful in conservation of these mammals too. This is also helpful to increase the productivity of cattle and livestock farming in alpine area. These are prey species of large carnivore like snow leopard, and grey wolf (protected species of Nepal). Therefore, further study should be done on pika and its food to conserve prey and predator species in Himalaya and to make better livelihood of local people.

It is reported pika meat used as traditional medicine in western Himalaya of Nepal. Local tribes in Central Asia use pika fecal as traditional medicine too. Peoples in Southwest China, Mongolia and Kazakhstan feed on pika meat. Fur of pikas were used to make felt hat in Second World War and were consumed as source of meat (protein) too. So we should study more detail about using pika for socio economic development of people living in remote Himalayas of Nepal as medicinal and food values.

This research shows pika population density is decreasing and it shows that pika is lower elevation are either migrated upward or locally extinct. It need further and long term research on physiology as well as behaviour of pika toward changing climate. This is preliminary and base in study on pikas of Langtang National which distribution pattern and climatic data of the particular place can suggest pika can be used as model animal to study about climate change and its impact in Himalayan ecosystem.

CHAPTER 6

6. SUMMARY

Pika is neglected, small mammal belonging to hare group lagomorphs. In Nepal, the pika research starts from mammal survey in Tibetan Side of Everest region by Thomas and Hilton (1922). They reported two species of pika in Nepal side. In 70, years we have only literatures based on reviews and speculations. Nepal Himalaya regarding ecology of pika has a significant gap in pika research. The research has fulfilled this huge gap in information of pika of Nepal Himalaya. This research has been conducted to obtain all the possible data on the ecology, diversity and influence of climatic change in pikas species of Langtang National Park. The study also explore the threats and human pika interaction in different habitats.

Quadrat, transect and block design method was applied to calculate population distribution, density. The study was carried in the trail transect of 53 Km length and 200 m wide in two routes (Ghodatabela, Langtang village, Mundoo village, Singdum village, Thulo Dhunga (near Kyanging valley), Kyanging, Langtang Lirung glacier, Lanshisa Kharka (way to Yala peak) in Langtang valley route. Similarly Bhanjyang (near Chandanbari), Dimsa, Chandanbari, Cholangpati, Polangpati, Barnagoth, Odhar Kharka, Laurebina, Gumba, Gosainkunda, Suryakunda, Laurebina Pass (way to Surya peak), Phedi, Thadepati and Magingoth in Gosainkunda route). Observation was done adjoining parts of these routes up to assessable area.

Scan sampling method was applied to collect behavioural data. Focal scan sampling was done at interval of 1 minute. Nutrients like protein, Calcium, Phosphorus, potassium, total ash, moisture content, cellulose (C), Hemi-cellulose (HC), Acid Detergent Lignin (ADL) and Neutral Detergent Fiber (NDF) was calculated from six most consumed forage plants collected during observation from different habitats.

Meteorological data were collected from Department of Hydrology and Meteorology (DHM) recorded in meteorological station in Kyanging (3900 m). Eighteen Temperature data logger (DS1921G Thermochron iButtons, Maxim Integrated Products, Sunnyvale, CA, USA) were installed in pika's habitat with difference of 200m elevation gradient in both route of Langtang National Park for recording temperature per day in interval of 90 minutes to record the temperature of burrows of pikas.

Pika in Langtang is known as “Bhragomjin” and religiously respected. Among five species of pikas recorded in Nepal, only large eared pika (*Ochotona macrotis*) and Royle’s pika (*Ochotona roylei*) are found in Langtang National Park. They both have broadly similar structure and habitat. They were sympatric in Laurebina, Langtang, Phedi and Thadepati area.

Abundance, behaviour and forage selection of pika were observed in three different habitats: forest and its edge area, subalpine area and alpine talus area. *Ochotona roylei* were observed at elevation at Dimsa, 3005 masl, the lowest elevation of pika encounter in Langtang National Park. This species was observed in all three habitats above this elevation but *O. macrotis* was not found in forest and its edge habitat. In Thadepati, Laurebina and Langtang, pika use to enter to local peoples’ home, hotels, lodges as well as cowshed frequently. In these places, due to such behaviour, Royle’s pikas were more habituated to human presence.

Age (Juvenile and adult) determination was categorized according to their body weight and size. The individual below 90 grams were categorized as juvenile while above that weight was considered adults.

The Royle’s pika inhabits in forest were dark coloured than other habitats. The head shoulders and fore part of the body are bright chestnut coloured. The remaining of the dorsal surface is dark grayish rufous. Ventrally, the colouration ranges from white to grayish-white to dark gray. Pikas’ have minor colour variation seasonally. The winter body fur colouration is not vary but little darker than summer. Juveniles were observed only in summer and rainy season and they had brighter colouration that adult. Royle’s pika in forest area were comparatively dark in colour than Royle’s pika inhabits in open area. They were difficult to notice due to camouflage with grass, dry leaves and shadow.

The average body length Royle's pika (*Ochotona roylei*) was 138.5mm (SD = 1.29), hind limb 62.25mm (SD = 0.95), fore limb 52.5 (SD = 0.57) mm, external ear pinna 22.75 mm (SD = 0.96), the length of whisker was 102.12mm (SD = 0.85) and weight 139.7 gm (SD =3.77).

Large eared pikas (*Ochotona macrotis*) were observed above 3500 masl. They are very swift running and active. They were not observed near human habitat as Royle's pika. The Large eared pika pelage colouration was varying to their habitat type and seasons.

The average morphological measurement of *O. macrotis* was as follow: body length 152 (SD=2.16) mm, hind limb 67.75 mm (SD=1.89), fore limb 60.25 mm (SD=1.7), external ear pinna 26.5 mm (SD=0.57), the length of whisker was 120.75 mm (SD=1.72) and weight 154.5gm (SD=3.41). Therefore, it is larger than *Ochotona roylei*.

Total Royle's pika observed in forest and its edge area was 73 (mean 7.3± 1.46) in ten quadrats and six field study. The adult juvenile ratio was 58:15. Juveniles were not observed in winter and dry season.

Ochotona roylei observed in subalpine with broken rocks area was 182 (SD = 4.89) and *O. macrotis* was 144 (SD = 6.96) with Adult Juvenile ratio 127:55 and 2:1 respectively. Similarly the total *Ochotona roylei* observed in alpine and talus area was 118 individuals (SD = 6.17) and *O. macrotis* was recorded 157 individuals (mean 15.7 SD = 8.91) with adult juvenile ratio 81:37 and 114:43 respectively. The density of pikas was the most in subalpine area with broken rocks. It was the maximum in summer and rainy season and the least at dry/winter season.

There is no significant relation between population distribution in subalpine area and alpine area for both species. The comparison between adult with adult has no significance (p=0.521), similarly, juvenile with juvenile had no significance too (P=0.671). However, for *O. roylei*, its population in forest area was significantly smaller than in subalpine area (p=0.014) and the test between adults (p=0.031) and Juveniles (p=0.048) also gives the similar result.

The behaviour of both species of pikas were observed and recorded by using focal scan sampling in time interval of one minute. Behaviour of pika was observed from 5:30 to 19:30 during summer and from 6:30 to 17:30 during winter. To observe nocturnal behaviour camera traps (Bushshell HD Model No. 119477) were used. Total field time (time spent in field) for recording behaviour of *Ochotona macrotis* was 17,640 minutes in summer and 9,900 minutes in winter and for *Ochotona roylei* was 12,168 minutes and 1,413 minutes respectively.

The percentage of activeness (external activities) of *Ochotona macrotis* and *Ochotona roylei* was 63.32% in summer and 11.14% in winter and the percentage of activeness 68.98% in summer and 14.27% in winter respectively.

The adult *Ochotona macrotis* shows musing (25.34%), feeding (23.02%), foraging (20.22%), inside burrow (15.45%), grooming (9.23%), galloping (5.084%), chasing (0.912%) and calling (0.74%) (N=9757 minutes) in summer. In winter, adult *O. macrotis* were observed musing (52.22%), feeding (6.71%), foraging (7.71%), inside burrow (21.21%) and grooming (12.15%). (N=1103minutes). There were no record of chasing, calling and galloping during winter. The juvenile of *O. macrotis* were not observed in winter, their external time budget (percentage) in summer was foraging (28.59%), feeding (20.45%), musing (16.70%), grooming (12.88%), inside burrow (10.69%), galloping (7.86%), chasing (2.20%) and calling (0.64%) (N=1413 minutes).

The adult *Ochotona roylei* shows feeding (26.10%), musing (24.10%), foraging 20.99%, inside burrow (12.99%), grooming (9.99%), galloping (4.01%), calling (0.99%) and chasing (0.84%) during summer. In winter those behaviour of adult *O. roylei* were respectively 11.40%, 45.86%, 2.19%, 16.34% 13.66%, 0.78%, 0% and 0.28% (N=1413minutes). The juvenile of *O. macrotis* were not observed in winter, their external time budget in percentage in summer was feeding (29.19%), foraging (24.68%), musing (17.73%), inside burrow (15.19%), grooming (7.55%), galloping (4.17%), calling (0.85%) and chasing (0.63%) (N=3192 minutes).

There are no significant difference between total behaviour of adult *O. macrotis* and adult *O. roylei.* The t-pair test between behaviours them gives the results t= 0.9473, df = 8, p-value = 0.3712. Similarly, there is no significant difference on behaviour of juveniles *O. macrotis* and juvenile *O. roylei* (t = 2.1031, df = 8, p-value = 0.0686).

The t-pair test between behaviour of adult *Ochotona macrotis* in different season give the significant different results in behaviour pattern with different seasons (t = 3.6253, df = 7, p-value = 0.00845). Similarly, for *Ochotona roylei* behaviour of different seasons give the significant different result between behaviour pattern with seasonal change (t = 3.3875, df = 7, p-value = 0.01164; <0.05).

Pikas' external activities were more from early morning before sunlight touch the ground to around 10 AM. After 10 AM, their external activities decreases, very few individual were observed during late morning and daytime in all seasons' field study. However, around 3 PM onward their external activities increases and were observed active even after sunset before pitch dark.

Pikas (combining both species) were observed grooming 9.81% of its external time budget. The grooming was done in three ways; grooming by using hind limb, grooming by fore limb and grooming by mouth (self-biting or auto-grooming)). Groomed by other individual was not observed. They groomed in all shifts and all seasons and groom was maximum time in morning shift. Grooming was cleaning process in pika. Most frequent grooming indicates that pika clean its body and might have ecto-parasite (!). However, flea or lice were not recorded in any captured pikas.

Musing is common behaviour of pikas in all seasons and shifts of a day. They spent 24.17% of total external time budget in musing. In day shift, more than 50% of their time budget was spent in musing. Musing was specially observed in sunlight so this is like sun basking behaviour. However, pikas were very often observed musing even there is no sunlight and breezing cold wind. Musing extends from very short (less than 1 minutes) to long musing (more than 15 minutes continuously).Total 206 times call was heard in total 25,854 minute observation. Among these calling, *O. macrotis* were observed and listened for 81 times and *O. roylei* for 116 times. No calls were heard in winter except four calls by *Ochotona roylei* at Phedi (sub-alpine area). There were two types of calling short call ''chi chi' and long call 'Chirrr…rrr' but the significance of calling is not known. Chasing was play like behaviour (most often in juveniles). Adults chase each other too, adult also chased juvenile but fight or biting between them were not observed. Chasing by adult-to-adult was not likely to territorial behaviour: in some incidents, chasing leads to mating. Total observed chasing behaviour was less than 1%.

During this study period, they were observed mounting for two times. They were observed mounting for 3-5 seconds. This incidents were observed afternoon before sunset. Pikas were also noticed performing parental care in summer. Both male and female were involved in caring their juveniles.

Gosainkunda Lake and its association in Langtang National Park are famous high altitude lakes. It is one of the Ramsar listed lake. Here every year thousands of pilgrims visit for their holy cause. This movement of people is increasing anthropogenic pollution in Langtang National Park and pika habitat. Pollutants were especially plastic, paper, cloths, bottles, used batteries and other non-degradable wastes. In different field works pollutant were observed in pika habitat especially in Gosainkunda area.

Pika discharged pellets as fecal matters. The number of pellets was different in adult, juveniles, and size varying from 1.8 mm to 2.1 mm. Pikas deposit two kinds of fecal droppings: hard brown round pellets and soft caecal pellets. The soft caecal pellets greenish-black, shiny with more moisture, and larger. The pellet numbers vary from seven to 12 in single discharge. Pika is coprophagous animal; they feed on their own caecal pellets. People on the wall of hut also observed them feeding on cow-dung dried (for cooking fuel). Pikas were rarely observed drinking water. Delicate and green plants will supply the major source of water to them. However, they were observed licking the water on the surface of stone. It licked for 5-6 times by using tongue. Pikas were also observed very often-licking rock and soil during January, March and April. This is dry season with very dry plants. Pika might have licked rocks and soils for fulfillment of required minerals.

Pika tears the leaf or petiole of the plants, which are larger with broad and large leaf, carry it to a few meters distance near big rock or open ground, and feed there. After consumption of carried plant parts, pika again repeat cutting the large part of plant similar way and move to same place for feeding. Hoarding food or construction of hay pile for winter use when food habitat is mostly covered by snow is common in practice. However, pika in Langtang is very poor to this behaviour. Only seven hay piles were observed during winter season. There is variation of nutrient content in plant or plant parts in different altitudes. The content seems true even same species of plants and plant parts. However, there is no effect of altitude to the value of nutrients of different plants consumed by pika.

Mean minimum temperature of Langtang national park is increasing significantly in all seasons and months but mean maximum temperature has not significance change. Precipitation pattern is shifting. Less rain or snow in winter affecting temperature of the burrows of pikas. It is affecting acute cold stress to pika. The temperature of mid elevation of study areas (3300m to 3600 m) is almost constant. The temperature inside the burrows in these areas is cooler in hot summer and warmer in cold winter. The temperature of higher elevation (above 3900m) is warmer than lower elevation in summer and very cold in winter. There is 3.2^0C (0.64^0C/100m) changed from elevation of 3000 masl to 3500 masl. Similarly it was 2.25^0C (0.46^0C/100m) in between 3500 masl and 3980 masl and 2.81^0C (0.453^0C/100m) in between 3980 masl to 4600 masl elevation.

Pikas in Langtang were not observed below 3000 m; they are migrating either upward or locally extinct at lower elevation. Population density of pikas was highest (12.3 individual/ha) at the elevation range of 3000 masl to 3600 masl (subalpine area). The foraging plants in this habitat had the maximum nutritional value like in protein, hemi-cellulose and well as the minerals like calcium and potassium were also highest in this habitat among same species of plants and different species of plants. The temperature pattern shows the both maximum temperature and minimum temperature was changing in forest area and alpine talus area. In subalpine area both summer and winter is warmer (neither hot nor acute cold) than other. This all phenomenon shows subalpine area with broken rocks was preferable habitat for pikas in Langtang national Park. The change in temperature one of the factor that effect population distribution of pika but the nutrition and available food and forage plants also affect the distribution of pikas. Therefore, pikas may not only migrate upward or locally extinct at lower elevation but this effect may be there at higher elevation. The average maximum ambient temperature and temperature inside burrow same at Kyanging (5.47^0C) in winter The ambient mean minimum temperature of winter was -2.3^{0}C but inside burrow was very low (-5.32^{0}C). This pattern of temperature supports the insulation effect of snow. The temperature inside the burrow was decreasing that acute cold stress to pika in winter. So, pikas in Langtang was facing climate change but their population was affecting not by increasing heat in summer but increasing minimum temperature in winter that melt the snowpack and reduce insulation effect. So, on the basis of present research it can be suggested that pika are under threat of thermal stress not because of heat or hot temperature but due to acute cold caused by increasing in minimum temperature in Nepal Himalaya.

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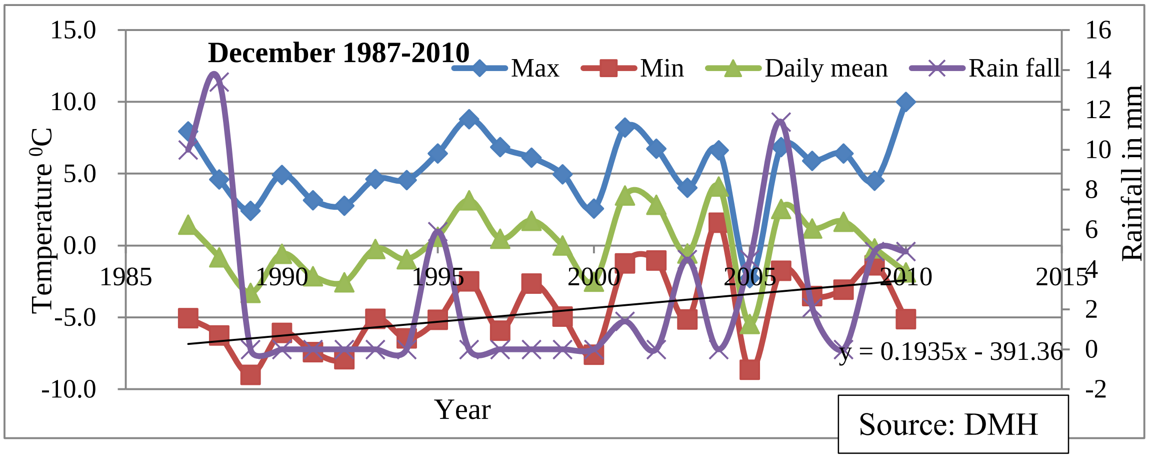
APPENDIX

A. List of thirty species of pikas of the world(Chapman and Flux, 1990; Hoffmann and Smith, 2005)

Common Name	Scientific Name
1. Afghan pika,	*Ochotona rufescens*
2. Alpine pika,	*Ochotona alpina*
3. American pika,	*Ochotona princeps*
4. Black pika,	*Ochotona nigritia*
5. Chinese red pika,	*Ochotona erythrotis*
6. Collared pika,	*Ochotona collaris*
7. Daurian pika,	*Ochotona dauurica*
8. Forrest's pika,	*Ochotona forresti*
9. Gansu pika,	*Ochotona cansus*
10. Gaoligong pika,	*Ochotona gaoligongensis*
11. Glover's pika,	*Ochotona gloveri*
12. Himalayan pika,	*Ochotona himalayana* **
13. Hoffmann's pika,	*Ochotona hoffmanni*
14. Ili pika,	*Ochotona iliensis*
15. Koslov's pika,	*Ochotona koslowi*
16. Ladak pika,	*Ochotona ladacensis*
17. Large-eared pika,	*Ochotona macrotis*
18. Moupin pika,	*Ochotona thibetana*
19. Muli pika,	*Ochotona muliensis* **
20. Northern pika,	*Ochotona hyperborea*
21. Nubra pika,	*Ochotona nubrica*
22. Pallas's pika,	*Ochotona pallasi*
23. Plateau pika pika,	*Ochotona curzoniae*
24. Royle's pika,	*Ochotona roylei*
25. Silver pika,	*Ochotona argentata*
26. Steppe pika,	*Ochotona pusilla*
27. Thomas's pika,	*Ochotona thomasi*
28. Tsing-ling pika,	*Ochotona huangensis*
29. Turkestan red pika,	*Ochotona rutile*
30. Turuchan pika,	*Ochotona turuchanensis*

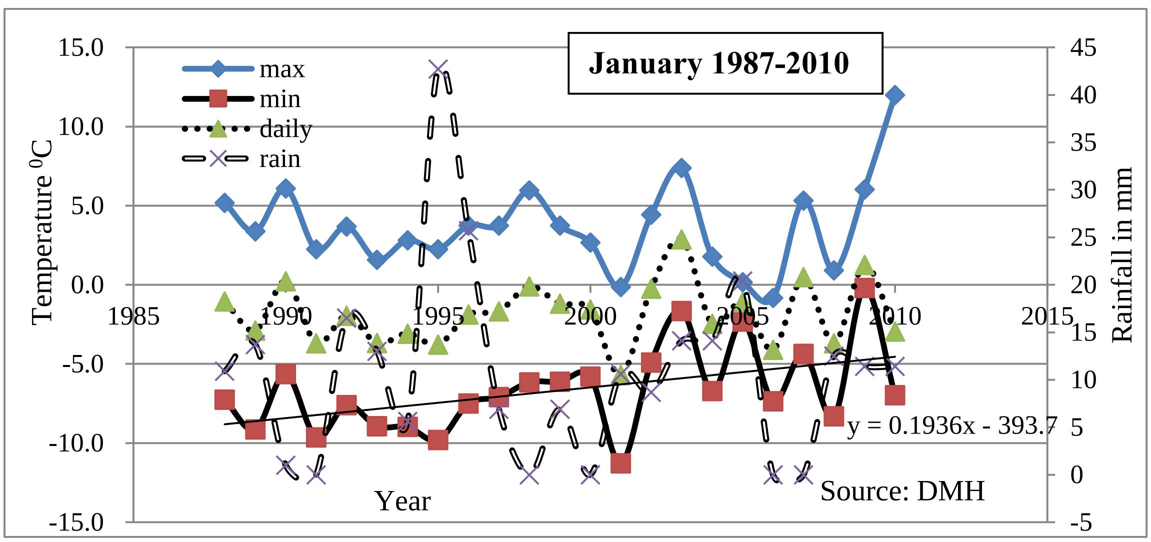
** Indicates pika species not included by Lissovsky (2014) in world pika list.

B. Month wise temperature and rainfall pattern 1987 to 2010, LNP



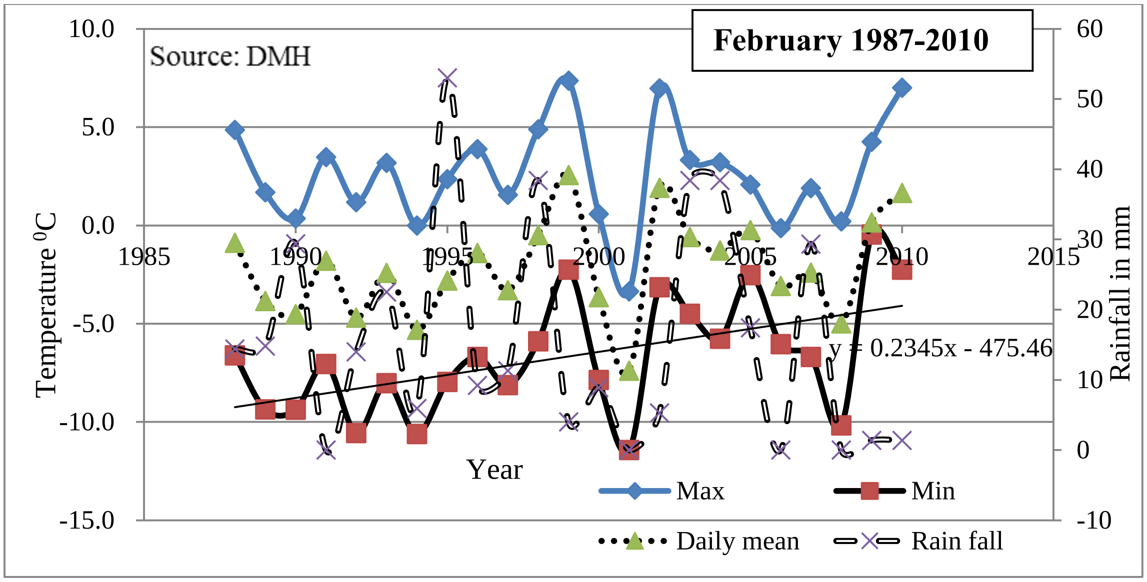
Maximum Temp	Daily Mean Temp	Minimum Temp	Rainfall
y = 0.0564x - 107.38	y = 0.0661x - 132.02	y = 0.1935x - 391.36	y = -0.1668x + 337.02
R^2= 0.0244	R^2= 0.0395	R^2= 0.2571	R^2= 0.0673
P-value = 0.466083	P-value =0.351662	P-value=0.011445	P-value=0.931233

Figure 59: Temperature and rainfall pattern of December 1987-2010, LNP.



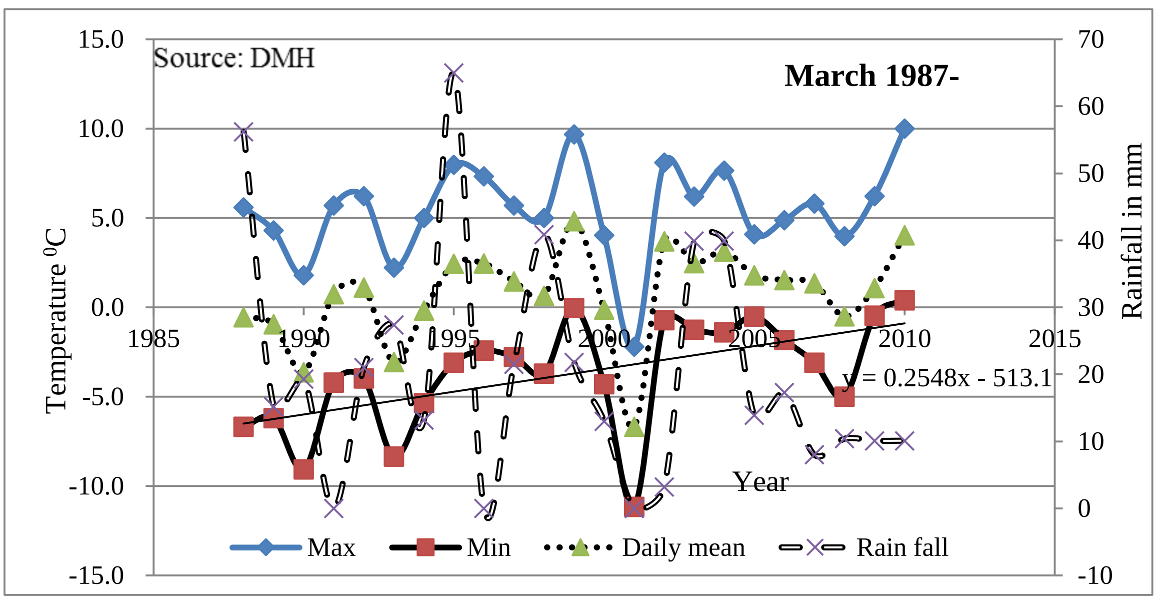
Maximum temp	Daily Mean temp	Minimum Temp	Rainfall
y = 0.0453x - 86.983	y = 0.0436x - 88.892	y = 0.1936x - 393.7	y = -0.0995x + 209.57
R^2= 0.012	R^2= 0.0221	R^2= 0.2391	R^2= 0.0047
P-value = 0.619229	P-value =0.498746	P-value=0.017883	P-value=0.756715

Figure 60: Temperature and rainfall pattern in January to March 1987 to 2010.



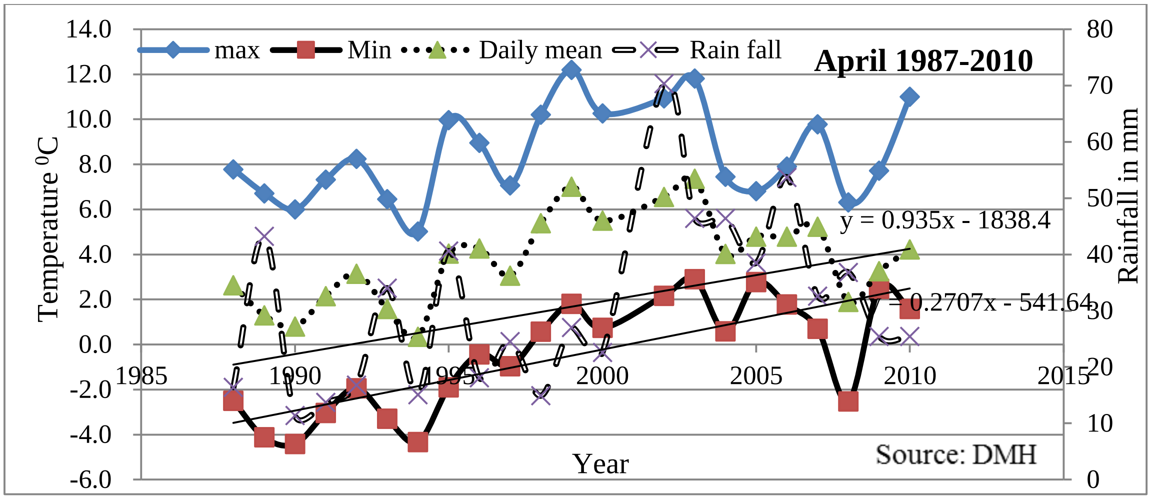
Maximum temp y = 0.0341x - 65.55 R ²= 0.008 P-value = 0.684873	Daily Mean temp y = 0.1092x - 220.5 R ²= 0.0891 P-value =0.166611	Minimum Temp y = 0.2345x - 475.46 R ²= 0.277 P-value=0.009881	Rainfall y = -0.3905x + 796.18 R ²= 0.0296 P-value=0.432233

Figure 61: Temperature and rainfall pattern in February 1987 to 2010.



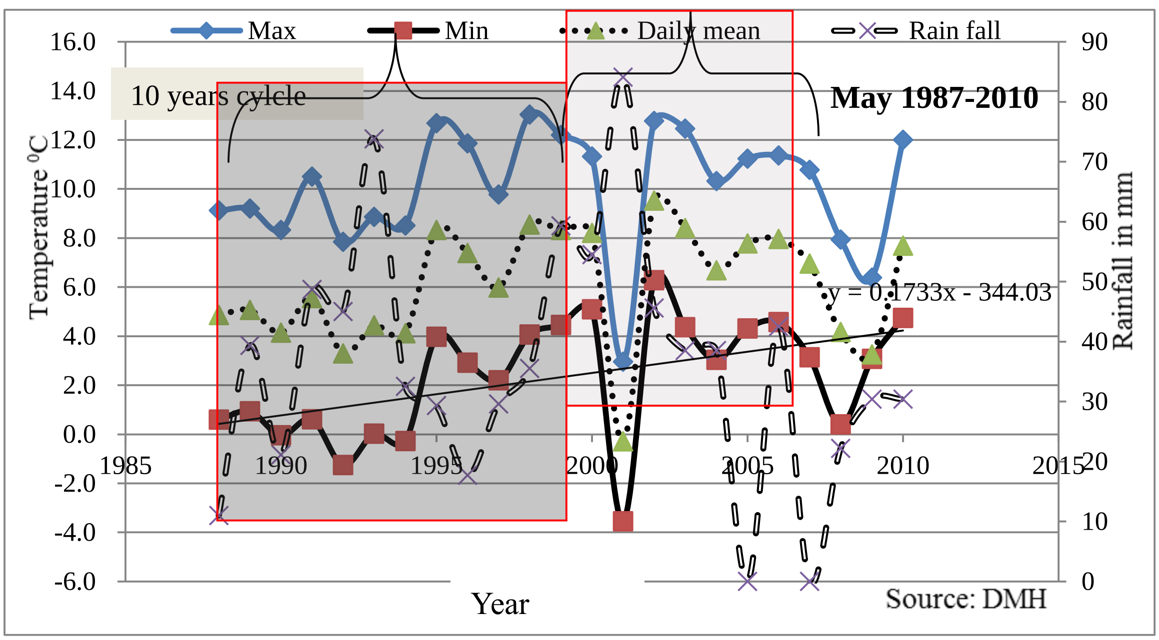
Maximum temp y = 0.0809x - 156.34 R ²= 0.0435 P-value = 0.339779	Daily Mean temp Y=0.1374x - 273.95 R ²= 0.1275 P-value =0.094461	Minimum Temp y = 0.2548x - 513.1 R ²= 0.3217 P-value=0.004768	Rainfall y = -0.7008x + 1421.3 R ²= 0.0742 P-value=0.208571

Figure 62: Temperature and rainfall pattern in March 1987 to 2010.



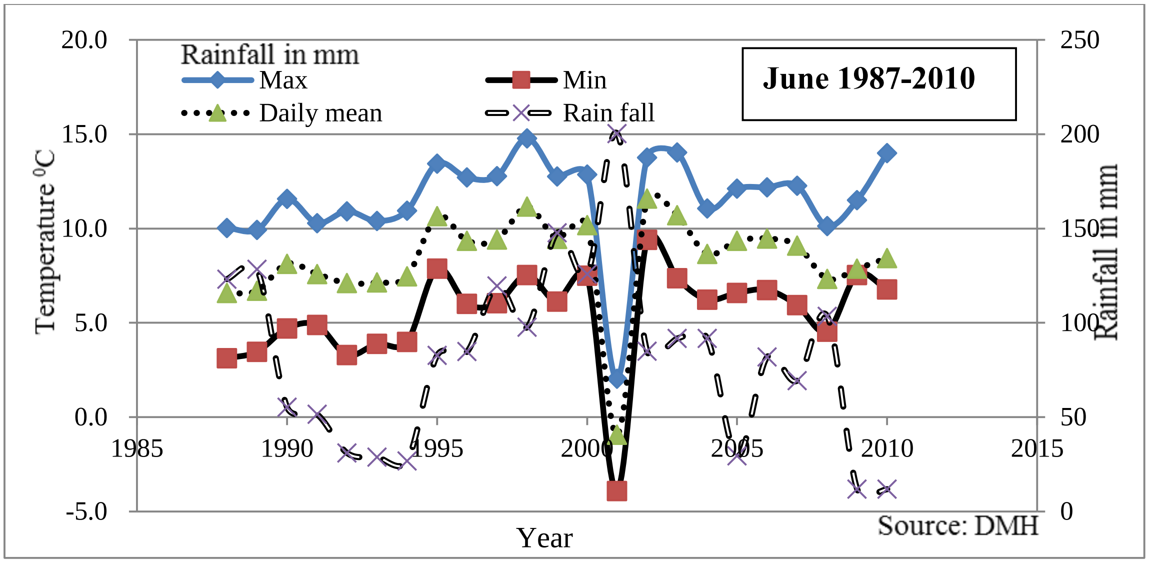
Maximum temp	Daily Mean temp	Minimum Temp	Rainfall
y = 0.0952x - 181.7	y = 0.1415x - 279.	y = 0.2707x - 541.6	y = 0.935x - 1838.4
R^2= 0.106	R^2= 0.2473	R^2= 0.5762	R^2= 0.182
P-value= 0.1393	P-value=0.01853	P-value=00.0042	P-value=0.0477

Figure 63: Temperature and rainfall pattern in April 1987 to 2010.



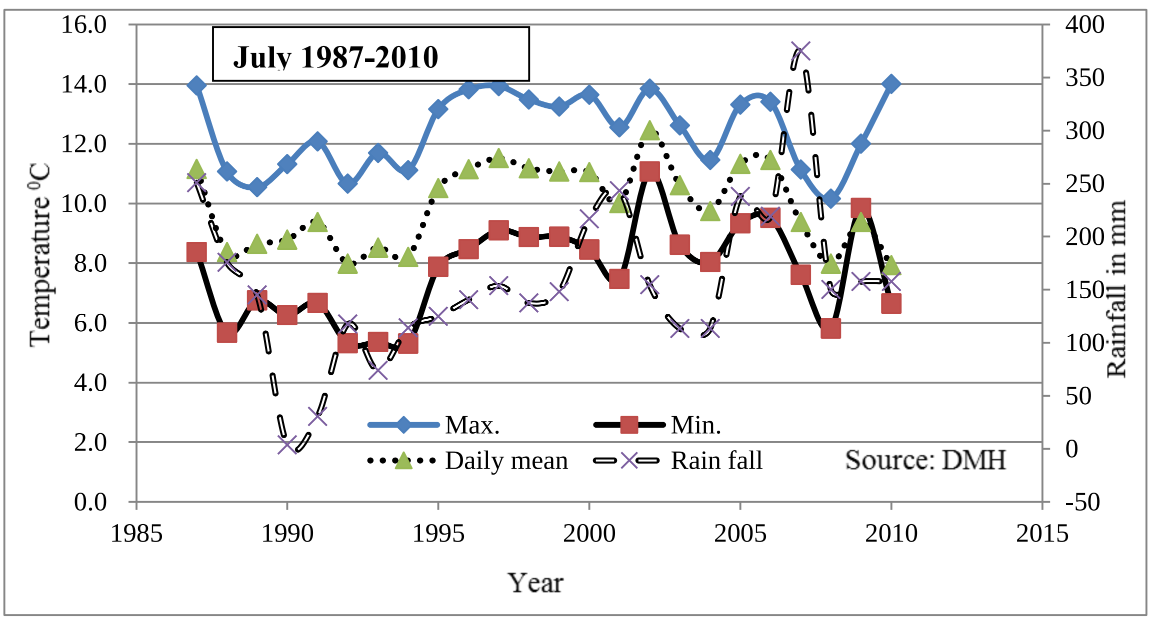
Maximum temp	Daily Mean temp	Minimum Temp	Rainfall
y = 0.0365x - 62.951	y = 0.083x - 159.81	y = 0.1733x - 344.03	y = -0.4321x + 899.86
R^2= 0.0106	R^2= 0.0567	R^2= 0.2317	R^2= 0.0206
P-value= 0.6408	P-value =0.27399	P-value=0.02004	P-value=0.51307

Figure 64: Temperature and rainfall pattern in May 1987 to 2010.



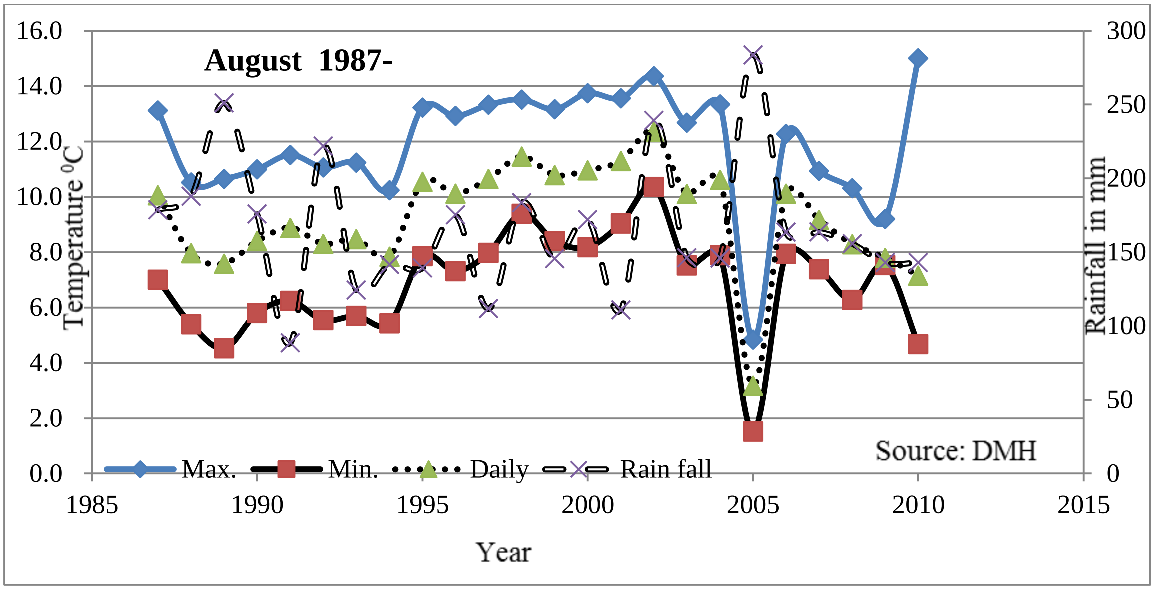
Maximum temp	Daily Mean temp	Minimum Temp	Rainfall
y = 0.0634x - 115.2	y = 0.0572x - 106.06	y = 0.126x - 246.4	y = -0.8914x + 1863.7
R^2= 0.0292	R^2= 0.0243	R^2= 0.1051	R^2= 0.0163
P-value= 0.4359	P-value=0.52239	P-value=0.13125	P-value=0.56162

Figure 65: Temperature and rainfall pattern in June 1987 to 2010.



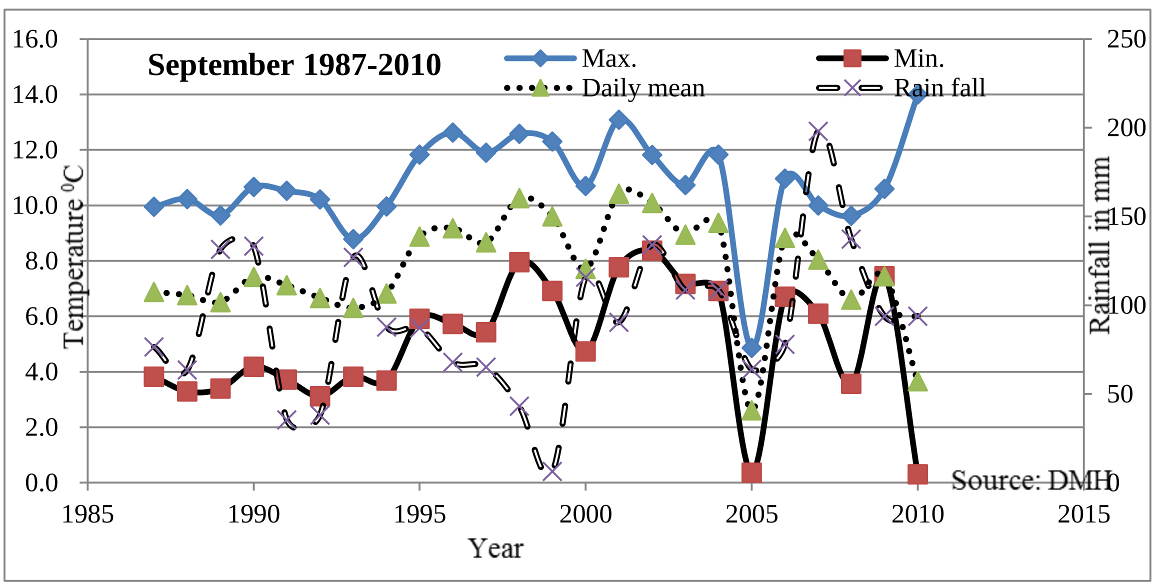
Maximum temp	Daily Mean temp	Minimum Temp	Rain fall
y = -0.0019x + 15.6	y = -0.0127x + 34.6	y = 0.0406x - 74.3	y = -0.4599x + 1085
R^2= 0.001	R^2= 0.0022	R^2= 0.0234	R^2= 0.0051
P-value=0.97713	P-value=0.82871	P-value=0.47563	P-value=0.74133

Figure 66: Temperature and rainfall pattern in July 1987 to 2010.



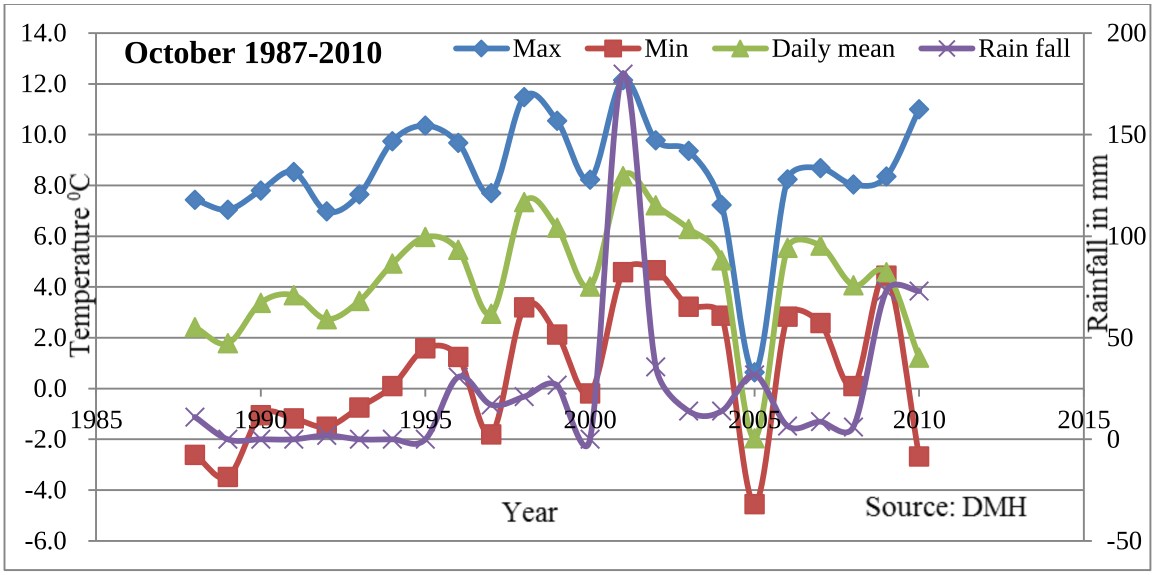
Maximum temp y = -0.0019x + 15.62 R^2= 0.001 P-value=0.97713	Daily Mean temp y = -0.0127x + 34.648 R^2= 0.0022 P-value=0.82871	Minimum Temp y = 0.0406x - 74.335 R^2= 0.0234 P-value=0.47563	Rain fall y = -0.4599x + 1085.4 R^2= 0.0051 P-value=0.74133

Figure 67: Temperature and rainfall pattern in August 1987 to 2010.



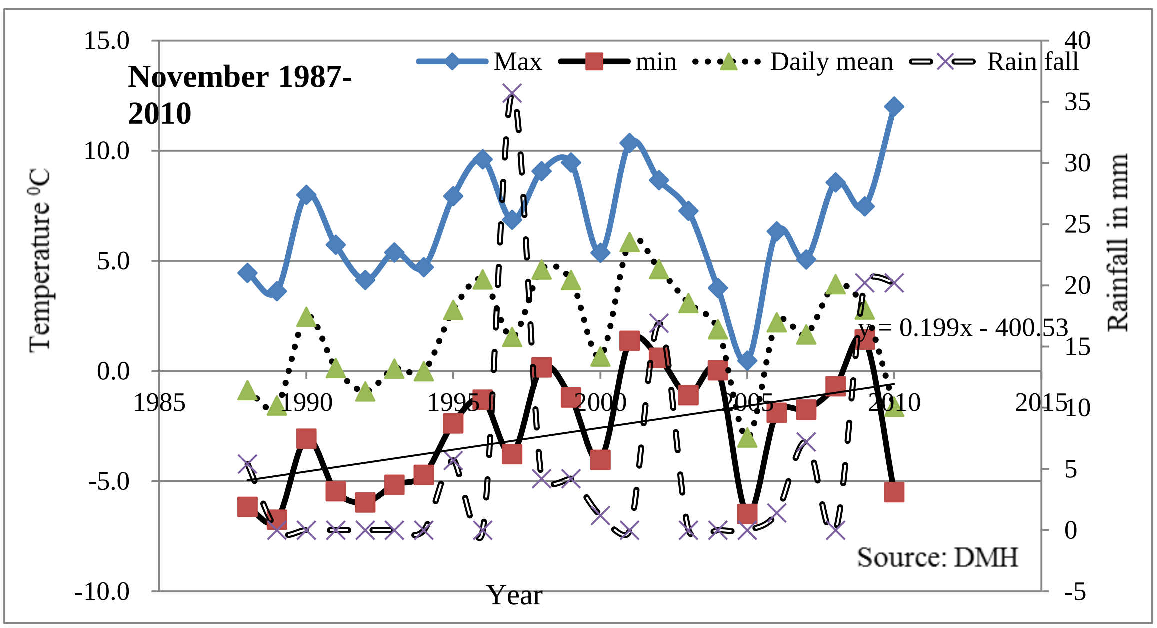
Maximum temp y = 0.0284x - 45.848 R^2= 0.0126 P-value= 0.6019	Daily Mean temp y = -0.0045x + 16.634 R^2= 0.0003 P-value= 0.9389	Minimum Temp y = 0.0612x - 117.27 R^2= 0.0382 P-value= 0.3602	Rainfall y = 1.6343x - 3175.2 R^2= 0.0771 P-value= 0.1890

Figure 68: Temperature and rainfall pattern in September 1987 to 2010.



Maximum temp	Daily Mean temp	Minimum Temp	Rainfall
y = 0.0115x - 14.53	y = 0.0381x - 71.725	y = 0.1645x - 328.27	y = 2.179x - 4331.8
R^2= 0.0012	R^2= 0.0127	R^2= 0.1693	R^2= 0.1366
P-value = 0.875343	P-value = 0.608859	P-value= 0.0510	P-value= 0.0825

Figure 69: Temperature and rainfall pattern in October 1987 to 2010.



Maximum temp	Daily Mean temp	Minimum Temp	Rainfall
y = 0.0991x - 191.4	y = 0.0796x - 157.4	y = 0.199x - 400.53	y = 0.3811x - 756.5
R^2= 0.0644	R^2= 0.0523	R^2= 0.2592	R^2= 0.0783
P-value = 0.242716	P-value =0.294073	P-value= 0.013106	P-value= 0.196036

Figure 70: Temperature and rainfall pattern in November 1987 to 2010, LNP.

C. Abstracts of published articles

National Journals and Conferences

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Population and comparative behaviour of *Ochotona roylei* and *Ochotona macrotis* in Gosainkunda Lake area, Langtang National Park, Nepal

Narayan P. Koju, Mukesh K. Chalise and Randall C Kyes*

Central Department of Zoology, TU, Nepal

*University of Washington, USA

ABSTRACT

Study on the behaviour of pika (*Ochotona roylei* and *Ochotona. macrotis*) was carried out during the months of July and August 2011 in Gosainkunda, Langtang National Park (LNP), Nepal. Pika inhabits in the talus habitats of the alpine area. Thadepati (3651 masl), Phedi (3825 masl), Gosainkunda (4436 masl), and Laurebina (3903 masl) were selected for behaviour recording. Quadrats of 50 m × 50 m were randomly plotted at each site except in Phedi. Only two species of pika were recorded in those areas: *Ochotona macrotis* was 75 individuals and *Ochotona roylei* 49 individuals. The ratio of age group adult and infant in *O. macrotis* was 29:46 and *O. roylei* 16:33 population with density 21/ha and14/ha, respectively. Eleven pikas were observed for 455 min to record their behaviour from 5:30 AM to 19:30 PM in each day. Feeding, foraging, musing, grooming, chasing each other (playing) were the recorded behaviour. They were active at dawn and dusk but were not observed during rainy period. They spent their 26% of time in feeding, 24% in musing, 16% in foraging, and 11% in grooming. Pikas were observed digging soft rocks, soil and mosses on the rock before discharging pellets.

Key words: *Ochotona macrotis, Ochotona roylei*, behaviour, Nepal.

UGC Journal 1, 74-82., 2012

Seasonal survey of the Large eared pika (*Ochotona macrotis* Günther, 1875) at Langtang National Park, Nepal

Narayan P. Koju[1] Mukesh K. Chalise, PhD[1] and Randall C Kyes, PhD[2]

[1]Central Department of Zoology, TU

[2]University of Washington, USA

Abstract

Study on seasonal survey of the large eared pika (*Ochotona macrotis*) was conducted from April 2011 to July 2012. In fifteen months, six field works were carried out for 102 full days covering spring/summer, rainy, autumn and winter season in Langtang National Park (LNP), Nepal. Pikas are diurnal, herbivorous and non-hibernating small mammals that inhabit talus in alpine areas. Large ear pikas were observed in Thadepati, Phedi, Ithang, Gosainkunda, Suryakunda, Laurebina, Langtang Valley, near river of Mundoo village and near Langtang Glacier (above Kyanging) in Langtang National Park. They were observed occupying higher elevations in only in Langtang village when observed sympatric with *Ochotona roylei*. Behaviour and pelage colouration was varying with season. Population density was found decreased by one individual per ha in fifteen months. Pika feed on different plants species and transfer plants for hay piles. Parental care was observed in summer.

Keywords: Pika, fur, population, forage, hay pile.

Sixth National conference on Science and technology, NAST, Nepal, Kathmandu, p. 70, 2012

Diversity of Pika (*Ochotona* species) and foraging activity in Gosainkunda area, Langtang National Park, Nepal.

Narayan P. Koju[1] Mukesh K. Chalise, PhD[1] and Randall C Kyes, PhD[2]

[1]Central Department of Zoology, TU, Nepal

[2]University of Washington, WA, USA

Abstract

Pika, the temperature sensitive small mammal inhabits in talus field in alpine area. The study was carried out during July and August 2011. Thadepati (3651masl), Phedi (3825masl), Gosainkunda (4428masl), and Laurebina (3903masl) were selected for recording feeding behaviour. Photography from different angle and video was taken to identify pika species, behaviour and forage plant species. Only two species of pika (*Ochotona macrotis* and *Ochotona roylei)* were recorded. Total number of 124 pikas was head counted in which 75 were *O. macrotis* and 49 were *O. roylei.* Pikas were observed for 20 days to record their feeding behaviours from 5:30 am to 19:30 pm using continuous Scan sampling method. They were active in dawn and dusk but were absent in rain. They spent their 26% time outside the burrow in feeding, and 16% foraging. Forty-three species of plants and their parts from eighteen families were recorded as food consumed by pika. Plants or their parts, which were eaten or taken more than 10 bites, were only recorded as Pika food plants. The biting speed of pika is 206 bites per minute. Rosaceae family revealed the highest plant species used by pika during that period. Both species of pika in this area were not observed collecting forage for winter hay pile in this season. Pika in Gosainkunda was recorded collecting plastics to their burrow. If the pollution is increasing year by year due to anthropogenic causes, the long-term survival and conservation of pika in the region may suffer.

Keywords: Pika species, foraging behaviour, Gosainkunda, LNP Nepal

Wildlife Week 18, 33-41, 2013

Forage selection and conservation threats on pika (*Ochotona* spp) at Gosainkunda area, Langtang National Park, Nepal.

Narayan P. Koju[1], Mukesh K. Chalise[1], and Randall C Kyes[2],

[1]Central Department of Zoology, TU, Nepal

[2]University of Washington, WA, USA

Abstract

Study on Forage selection and conservation threats on pika (*Ochotona* species) was conducted during the rainy season (July and August 2011) in Gosainkunda, Langtang National Park (LNP), and Nepal. Pikas are diurnal herbivorous non-hibernating small mammals that inhabit talus in alpine areas. Four study sites Thadepati (3651 masl), Phedi (3825 masl), Gosainkunda (4380 masl), and Laurebina (3903 masl) were selected for recording feeding behaviour. Photography from different angle and video was taken to identify pika species, behaviour and forage plant species. Only two species of pika *Ochotona macrotis* and *Ochotona roylei* were recorded in those areas of LNP in which 75 were *O. macrotis* and 49 were *O. roylei* with density 21/ha and14/ha respectively. Pikas were observed for 20 days regularly from 5:30 am to 19:30 pm using continuous Scan sampling method. They were active in dawn and dusk but were absent in rain. They spent their 26% time outside the burrow in feeding, and 16% foraging. Plants or their parts, which were eaten or taken more than 10 bites, were only recorded as Pika food plants. Forty-three species of plants and their parts from eighteen families were recorded as food of pika. Rosaceae family revealed the highest plant species used by pika during that period. Leaves of 43 plants species, leaves along with petiole of three species and leaves along with flower of ten plants species were consumed by pika. Both species of pika in this area were not observed collecting forage for winter hay pile in this season. Pika in Gosainkunda was recorded collecting plastics to their burrow. If the pollution is increasing year by year due to anthropogenic causes, the long-term survival and conservation of pika in the region may suffer.

Keywords: Food plant, parts *Ochotona macrotis*, *Ochotona roylei*, Nepal

Journal of Natural History Museum Nepal 27, 78-86, 2013

Royle's pika (*Ochotona roylei*) observation in Api Nampa Conservation area, Nepal

N. P. Koju and M. K. Chalise

Central Department of Zoology, TU, Nepal

Abstract

Pika study was carried out on the Southern base of Mt. Api in Api Nampa Conservation Area (ANCA) during June of 2012 and 2013. Pikas were observed for their population and behaviours. Feeding was observed more than 23 plants species including poisonous species to cattle. The presence of *Ochotona roylei* was confirmed while a doubtful individual was observed which is similar to *O. macrotis* species in morphology. Pikas raid the human supply sometime peeping into human shelter. Local people use pika meat to cure some diseases.

Key words: Pika, Population, Behaviour, Api Nampa

International Journals and Conferences

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Population abundance of Royle's pikas (*Ochotona* roylei) along altitudinal gradients in Langtang National Park, Nepal

Narayan P. Koju, Mukesh K. Chalise
Central Department of Zoology, TU, Nepal

ABSTRACT

The study on population abundance of pikas was carried out in Langtang National Park from June, 2011 to January, 2014. Six field works were carried out representing different seasons. The evidence of pika presence was recorded at 3005 masl as lowest elevation. Population abundance was studied categorizing study area into three habitats: forest area, subalpine area and alpine talus. Total 373 pika individuals were observed. Its population abundance was higher in summer than winter. The average density of pikas was 8.98 individual per hectare. Subalpine area had the highest average population density of pikas (12.8/hectare) and the least was in the forest habitat and its edged area (4/hectare). Population abundance of pika in Langtang is decreasing. Pikas habitat were shifted upward that shows either location extinction or migration at lower elevation.

Keywords: Altitudinal, Density, *Ochotona roylei*, Population.

Behavioral Adaptation of the Large Eared Pika (*Ochotona macrotis* Günther, 1875) At Langtang National Park, Nepal

Narayan P. Koju, Mukesh K. Chalise
Central Department of Zoology, TU, Nepal
Email: npkoju.2003@gmail.com

Abstract

The study was conducted from April 2011 to January 2014. In thirty months eight field works were carried out for 162 full days covering twice each in spring, /summer/rainy, autumn and winter season in Langtang National Park (LNP), Nepal. Pikas in Himalayas are prey species of snow leopard, bear, vulture, weasel and yellow throated martin. Large eared pikas were observed from elevation of 3560m (Thadepati) to 5000m (Lirung Glacier).They were sympatric with *Ochotona roylei* in Langtang valley, Phedi and Kyanging. Behaviour and pelage colouration was varying with season. Grooming, musing, calling, feeding, foraging, Chasing, inside burrow and Galloping behaviours were observed by focal scan sampling. Total 17640 minutes external behaviour of 43 pikas was recorded from 5:30 AM to 6 PM. Camera trap was used to record nocturnal behaviour.

Calling is regarded as major behaviour in pika. It is not only communication in intra-species but also information to predators; call brings predators closer to them than animals who do not call. Pikas may increase their chances of being preyed upon by calling. Similarly hoarding hay pile also exposes pika to predators. Calling and hoarding hay pile is very less (> 1%) in pikas of Langtang National Park. This may be the adaptation during evolution to avoid predators as Himalaya of Nepal has many pika predators.

The seasonal fur colour variation of *Ochotona macrotis* body was recorded near Gosainkunda Lake (N 28 ° 04'30.5" E085 ° 25'29.5' and elevation 4746m), on the way to Suryakunda for four seasons. In spring general colour of ventral side was pale brownish grey with an orange shade. Along the sides of the face, across the shoulders and from the nose over the occipital, the general greyish colour was tinged with rufous. Limbs were of yellowish colour with mixture of white. At the dorsal neck there was crescent patch of dark yellowish red colour. It might be the sign of maturation or sexual attraction to opposite sex as spring is their breeding season.

During summer brownish ventral was darker than spring with brighter colour at dorsal side. Above the snout in between the occipital there was reddish brown patch. In autumn the whole body of *Ochotona macrotis* was dense fluffy, pale grey with a tinge of straw-yellow. The ventral was darker than the dorsal. Frontal's yellowish patch seems reduced. Outer surface of pinna was greyish yellow but the internal was greyish white. Limbs were greyish too that is camouflage to dry surrounding on those seasons. In winter the dorsal colour was mixed with pale grey yellowish and black colour while ventral was greyish black. It might be an adaptation against cold climate.

Keywords: Pika, fur, colour, adaptation, Langtang, Nepal

Environment, biodiversity and Traditional System, Biotech Books, India, pp. 75-86, 2013

Ecology of Pika (*Ochotona* species.) in Gosainkunda area, Langtang National Park, Nepal.

Narayan P. Koju[1] Mukesh K. Chalise, PhD[1] and Randall C Kyes, PhD[2]
1Central Department of Zoology, TU, Nepal
[2]University of Washington, USA

Abstract

The study was carried out on the population status and behaviour of pika around Gosainkunda area of Langtang National Park, Nepal during July/August 2011. The pika is called "Bhragomjin" by locals and respects it as the symbol of Buddhist monk. Pika inhabits in talus field of the alpine areas. Thadepati (3651 masl), Phedi (3825 masl), Gosainkunda (4428 masl), and Laurebina (3903 masl) were selected for population survey and behaviour recording. Quadrats of 50m×50m sizes were randomly plotted in each site. Only two species of pikas were recorded in those areas and identified as *Ochotona macrotis* and *Ochotona roylei*. Total number of 124 pikas was head counted in which 75 were *O. macrotis* and 49 were *O. roylei*. The ratio of age group 29:26:20 for adult, infant and juvenile of *O. macrotis* are recorded while 16:23:10 found for *O. roylei* and the population density was 21/ha and14/ha respectively. Eleven pikas were observed for 455 minutes to record their behaviours from 5:30 am to 19:30 pm of the day. The behaviour recorded were feeding, foraging, musing, grooming and playing (chasing each other). They were active during dawn and dusk and were absent in rain. They spent their 26% time in feeding, 24% musing, 16% foraging, and 11% grooming. Pikas were observed digging soft rocks, soil and mosses on the rock before discharging pellets.). A pika (*O. roylei*) was observed transporting a piece of polymer sack. Sometime pikas do nuisance in local residence. Ten thousands of pilgrims visit Gosainkunda, the only Ramsar site in Langtang National Park each year in rainy season that is increasing the pollution year-by-year and perceived threat in the long-term survival and conservation of pika in this region.

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Comparing behaviors of the large-eared pika (*Ochotona macrotis*) in the Himalaya of Nepal with those of the American pika (*Ochotona princeps*)

Differences in the behavior of closely related species may indicate differences in ecology and species-habitat interactions. This phenomenon is important for understanding and conserving species of special concern. The behavior of *Ochotona macrotis* was studied in Langtang National Park (LNP), Nepal, using focal scan sampling. Data from 684 hours of sampling (representing 129 days and all four seasons) were compared with published data on *O. princeps*, to evaluate differences in food hoarding, calling, parental care, geophagy and fur colouration. In LNP, *O. macrotis* spent only 0.025% (0.075trips/hr) of its annual time budget in activities related to food hoarding, much less than reported for *O. princeps* (13 trips/hr) at similar elevations (3600-3900 masl). Although *O. princeps* makes strong and frequent calls, *O. macrotis* was observed calling only 0.92% of the time in summer and not at all in winter. Several behaviors observed in *O. macrotis* appear much less common in *O. princeps*. For example, adult *O. macrotis* were observed carrying young 2-3 times every 3-4 days in June, by biting the nape. In addition, *O. macrotis* was observed licking rocks and soil frequently (12% of foraging and 1.3% of total behavior) during winter. However, licking self-body parts, yawning and snow eating behavior reported in *O. princeps* were not observed in *O. macrotis*. Finally, seasonal changes in pelage colouration were more noticeable in *O. macrotis* than reported for *O. princeps*. Reduced hoarding and calling behaviors, and extended parental care, may be evolutionary adaptations to avoid predators.