DISTRIBUTION OF SMALL MAMMALS ALONG ALTITUDINAL GRADIENTS IN THE MID MOUNTAIN, NUWAKOT, NEPAL

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T.U. Registration No. : 5-2-33-119-2010

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A thesis submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in Zoology with special paper Ecology.

Submitted to

Central Department of Zoology

Institute of Science and Technology

Tribhuvan University

Kirtipur, Kathmandu

Nepal

Date: Aug 2018

DECLARATION

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

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RECOMMENDATION

This is to recommend that the thesis entitled "**DISTRIBUTION OF SMALL MAMMALS ALONG ALTITUDINAL GRADIENTS IN THE MID MOUNTAIN, NUWAKOT, NEPAL**" has been carried out by Mr. Shankar Karkee for the partial fulfillment of Master's Degree of Science in Zoology with special paper Ecology. This is his original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institutions.

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LETTER OF APPROVAL

On the recommendation of supervisor "**Prof. Dr. Tej Bahadur Thapa**" this thesis submitted by Shankar Karkee entitled "**DISTRIBUTION OF SMALL MAMMALS ALONG ALTITUDINAL GRADIENTS IN THE MID MOUNTAIN, NUWAKOT, NEPAL**" is approved for the Tribhuvan University in partial fulfillment of the requirements for Master's Degree of Science in Zoology with special paper Ecology.

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CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Shankar Karkee entitled "**DISTRIBUTION OF SMALL MAMMALS ALONG ALTITUDINAL GRADIENTS IN THE MID MOUNTAIN, NUWAKOT, NEPAL**" has been accepted as a partial fulfillment for the requirements of Master's Degree of Science in Zoology with special paper Ecology.

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ABBREVIATIONS AND ACRONYMS

Abbreviated form	Details of abbreviations
CBD	Conservation on Biological Diversity
DHM	Department of Hydrology and Metrology
IUCN	The International Union for Conservation of Nature
LMT	Local Mesh Trap
LPMP	Low-elevational Plateau with a Mid Peak
PFT	Pit Fall Trap
SMCRF	Small Mammals Conservation and Research Foundation
SSC	Species Survival Commission
TT	Tube Trap
TU	Tribhuvan University

ABSTRACT

Diversity and distribution pattern of small mammals were studied along altitudinal gradients of a mid-mountain of Shivapuri Rural Municipality-1, Nuwakot, Nepal. The study aimed to assesses diversity and altitudinal distribution pattern of small mammal species and comparison of trap efficiencies. Live trapping of small mammals by three types of trap (Local Mesh Trap, Tube Trap and Pitfall Trap) were performed at five trapping sites of altitude of 1,200 m, 1,500 m, 1,800 m, 2,100 m and 2,400 m by making two trapping grids of 50 m × 50 m in each site. Small mammal diversity and distribution along altitudinal gradients were analyzed by calculating diversity index, community evenness, community similarity and β diversity. Chi-square test, correlation test, Kruskal Wallis test and simple correspondence analysis were used for statistical analysis of significance variations of species richness, associations of species richness with altitude and trap success rates. Eight species of murid rodent and two species of soricid shrew were observed with diversity index of 2.06 and overall trap success of 11.55%. Slightly decreasing trend in species richness along altitudinal gradients was observed. But the correlation between species richness and altitude was statistically insignificant ($r = -0.41$, p-value > 0.5). The small mammal species richness and community composition varied greatly along altitudinal gradients with variation of dominant forest vegetation, understory vegetation structures and habitat complexity. *Apodemus sylvaticus* was found to be the most abundant rodent species where both shrew species showed poor diversity than rodents. *Niviventer eha, Mus musculus* and *Soriculus macrurus* were observed at lower gradient and *Apodemus sylvaticus* and *Alticola roylei* were observed at upper gradients. Similarly, *Bandicota bengalensis* and *Suncus murinus* were trapped at the middle of altitudinal gradients. Trap success rates and species specificity of three trap types varied greatly from site to site. LMT trapped more species and individuals with more trap success rate. Larger and smaller body sized species were mostly trapped by LMT and TT respectively. *Bandicota bengalensis* and *Rattus rattus* were only trapped by LMT and *Mus musculus* was only trapped by TT. But PFT trapped mostly smaller and medium sized species. Three types of trap used for small mammal sampling showed supplementary role for diversity of small mammals. It is concluded that diversity and distribution pattern of small mammals along altitudinal gradients varies on the basis of dominant forest vegetation types, understory vegetation, habitat heterogeneity and complexity. And different types of trap showed complementary role for sampling of small mammalian community.

1. INTRODUCTION

1.1 Background

Species are not evenly distributed on the Earth's surface. On moving either northwards or southwards from equator and from lower surrounding of mountain base towards mountain top, species richness, composition and abundances are differed and such differences are termed as latitudinal and altitudinal gradients of biodiversity respectively. The altitudinal gradient on the mountain is expressed by the formation of different vegetation zones (Clausnitzer and Kityo, 2001) and such gradients are directly related to climatic variables (McCain, 2005). Mountain landscapes, owing to their physical, topographic and climatic heterogeneity create a mosaic of habitats (Viterbi *et al*., 2013). The gradients in these abiotic factors strongly influence the distribution of floral and faunal species and therefore the changes in dominant communities and habitats (McCain and Grytnes, 2010).

Climatic factors change predictably with increasing elevation such as linear decrease in temperature, air pressure and increase in solar radiation and precipitation. Other abiotic factors that vary with elevation and can be important determinants of species richness include area, cloud cover and soil quality (McCain and Grytnes, 2010). The rapid rate of environmental change within relatively short geographic distance facilitates identification of mechanism that models species distribution and community assembly, which can be contrasted among taxa, through space or over time (Willing and Presley, 2016).

Patterns of diversity and their underlying mechanisms may vary among taxa, bio geographical region and species composition (Chen *et al*., 2017). Generally, there are four altitudinal distribution patterns of species richness: decreasing richness with increasing elevation , plateaus in richness across low elevations then decreasing with or without a mid-elevational peak and unimodal pattern with a mid-elevational peak (McCain and Grytnes, 2010) (figure 1). Decreasing richness patterns are those in which species numbers decline generally monotonically with increasing elevation. Low plateau patterns have consecutively high richness across the lower portion of the gradients and thereafter decreasing species richness. Low plateau patterns with a mid-elevational peak have high richness across low elevation with a diversity maximum found more at mid elevation. Mid-elevational peaks have a unimodel peak in diversity at intermediate elevation (Figure 1).

Biodiversity patterns are the result of the interaction of numerous contemporary factors and historical opportunities for allopatric speciation (Novillo and Ojeda, 2014). The explanations commonly offered for elevational patterns in species richness can be grouped into four categories; climatic hypothesis, spatial hypothesis, historical hypothesis and biotic hypothesis (Mena and Medellin, 2017). Climatic hypotheses are based on variation in abiotic variables such as temperature, rainfall, productivity, humidity and cloud cover (McCain and Grytnes, 2010). The spatial hypothesis includes the species area effect and spatial constraint (Mid-domain effect) (McCain, 2007). Evolutionary hypothesis includes speciation rate, extinction rate, clade age, and phylogenetic niche conservatism and biotic processes include ecotone effects, competition, mutualism, and habitat heterogeneity and complexity (McCain and Grytnes, 2010).

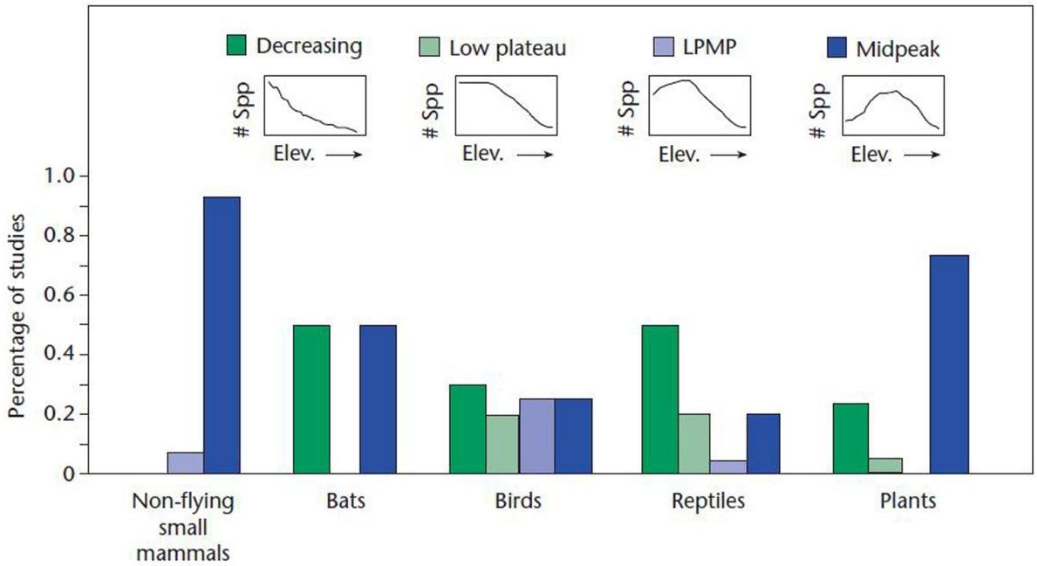

Figure 1, The percentage of the four main elevational richness patterns demonstrated on mountain gradients across the globe, including decreasing, low-elevational plateau, low-elevational plateau with a mid-peak (LPMP) and mid-peak for non-flying small mammals, bats, birds, reptiles and plants (McCain and Grytnes, 2010).

A global analysis of elevational diversity trends for non-volant small mammals revealed a clear pattern of mid-domain peak in species richness (Figure 1). This is explained by constraints posed which prevent species from extending their ranges below the lower or above the highest elevation (Krystufek *et al*., 2010). On the basis of population ecology, the hump-shaped pattern may result because of the dispersal of species from lower and higher elevations, resulting in the highest overlap of such dispersing populations at mid elevation, the extremes of the gradients (Fisher, 2011).

Generally the small mammal species richness along altitudinal gradients is driven directly by temperature and water (McCain, 2007), understory plant biomass (Gardner, 2011), vegetation complexity and habitat complexity (Bateman *et al*., 2010), habitat structure, area, productivity, predation, trampling and grazing, surrounding landscape and distance between similar habitats and maturity of habitats (Bantihun and Bekele, 2015). Species diversity, composition, relative occurrence and capture probability and population size of small mammals vary with vegetation type (Bantihun and Bekele, 2015).

Capturing is the ultimate method of sampling of small mammals for their inventory and ecological study. Live trapping has been considered as key techniques for monitoring small mammals, however live trapping encompasses different techniques which differ in their efficiency and specificity (Torre *et al*., 2010). Trapping methods strongly influence the sampling of small mammals and capturing efficiencies of small mammals varies according to the kind of traps, taxonomic groups, seasons and habitats (Alm *et al*., 2014).

No single trap type will capture individual members of a local ecological community of all species. Hence, in order to achieve a more complete sample, it is necessary to use a combination of sampling methods (Filho *et al*., 2006).

1.2 Small mammals

The term 'small mammals' is generally considered to any non-flying mammals weighting less than 1 kg adult weight (Barnett and Dutton, 1995). In practice the term is restricted to rodents, marsupials, insectivores and elephant shrews. The IUCN SSC (Species Survival Commission) Small Mammal Specialist Group is responsible for three orders of small mammals:- the rodents, tree shrews and the eulipotyphlans, made up of the shrews, moles, hedgehogs and solenodons. The mean body size of all rodent, insectivore and tree shrew species is less than 1 kg. Though, many mammalian orders have such small sized species, different authors and organizations considered and defined small mammal differently with great variation of orders and species inclusion. Such as, Rogozi *et al*. (2012) considered order Rodentia and Insectivora as small mammals. According to Pearch (2011) small mammals include five orders namely Scandentia, Lagomorpha. Rodentia, Eulipotypha and Chiroptera.

In case of Nepal, species of five orders (Eulipotyphla, Lagomorpha, Pholidota, Rodentia and Scandentia) are included as small mammals in the IUCN red list series of mammals of Nepal (Jnawali *et al*., 2011). Whereas, SMCRF (2012) included mammals up to ten kilograms body weight into small mammals. Then SMCRF included one hundred fifty one species of eight orders (Rodentia, Chiroptera, Carnivora, Eulipotyphla, Lagomorpha, Artiodactyla, Pholidota and Scandentia) of mammals of Nepal into small mammals.

1.3 Ecological roles of small mammals

Small mammals are important component of biological diversity. Major portion of ecological community is occupied by small mammal species in all types of ecosystem. Small mammals make up an important link in food chains as both prey and predators. Basically Rodent and shrew are important contributors to biodiversity of ecosystem (Mulungu *et al*., 2008).

Small mammals serve important ecological role as both primary consumers and prey item of carnivores, including raptors and many medium sized mammals. Small mammals regulate and maintain ecosystem functions through their influences on vegetation, soil and other animals (Sieg, 1987). They affect the structure, composition and distribution of forest communities through activities such as seed dispersal, pollution, and impact on insect population and as food for carnivore animals (McCain, 2005). Small mammals influence both physical and chemical properties of soils, prey on insects and occasionally other small mammals provide a prey base for carnivores and modify their environments in such a way as to provide habitat for other animals (Sieg, 1987). The change in small mammal abundance and distribution can affect the dynamics of other species as well (Chane and Virga, 2014). Small mammals are considered to be good bio-indicator of habitats because of their short life span, rapid population dynamics and low level of pressure on their population as result of hunting in comparison with large mammals (Barrier *et al*., 2006).

Some rodent species (less than 5%) are pest and cause significant losses to agricultural crops and stored food grains in many regions of the world (Aplin and Singleton, 2003). Rodents are considered as the second most important pest of upland farmers after insects (Ngaomei and Singh, 2017). A variety of viral and bacterial pathogens such as Hanta viruses, Arena viruses, *Yersinia pestis* and *Leptospira* sp. can be transmitted by rodents or by arthropods feeding on them, thus rodents form a potential threat for public health (Rogozi *et al*., 2012).

1.4 Objectives

General objective

The general objective of this study was to assess the altitudinal distribution of small mammals in the mid-mountain in Nuwakot, Nepal.

Specific objectives:

- To make an assessment of small mammalian species diversity.
- To assess elevational distribution pattern of species richness of small mammals.
- To compare trap efficiencies of different live traps.

1.5 Rationale of the study

Knowing the distribution of small mammals along an elevational gradient is critical to understanding the evolution and ecology of biotic system in any landscape and to designing conservation strategies to maintain those (Stanley *et al*., 2014). Elevational surveys of small mammals elucidate both specific and broadly general pattern that help explain the mechanism influencing the distribution of mammals along such gradient with significant implication for biogeographic analysis (McCain, 2005). Survey of small mammals provides baseline data for judgment of effect of climate change and other human interference. Elevational gradients serve as baseline for comparison of population declines, range shift and extinction risk. Nepal contains elevational gradients from lower tropical to upper alpine climatic zone within short north- south span. Hence identification of diversity trends and underlying factors and monitoring changes in temporal and spatial scale along altitudinal gradients explain whole spectrum of Nepal's biodiversity and make foundation for conservation and decision making (CBD, 2014). Therefore this study also helped to account for baseline information on species inventories, diversity and distribution of small mammals of Shivapuri Rural Municipality, Nuwakot, Nepal.

1.6 Limitations

- Broader altitudinal gradient of 300 m interval along only a single altitudinal transect was considered.
- All potential habitats of small mammals were not sampled due to limited size and number of trapping grids at each trapping altitude.
- Three types of traps used only on ground surface were not sufficient for capturing all possible small mammal community species.
- The species richness pattern along altitudinal gradients was assessed only on the basis of correlation between species richness and altitude.

2. LITERATURE REVIEW

2.1 Altitudinal distribution of small mammal diversity

For global analysis of distribution patterns and underlying hypotheses of mammalian diversity along altitudinal gradients, McCain (2005) used 56 data sets of elevational gradient study to test the predictions of a null model (the mid-domain effect) and climatic hypothesis and found a clear pattern of mid-elevational peak in species richness of non-volant small mammals and very few data sets fit entirely within a null model. Grytnes and McCain (2007) reviewed history of studies of elevational species richness pattern and observed elevational trend in species varies among group of organism and from area to area. They also found that most commonly observed patterns were decreasing richness with increasing elevation and a hump pattern with a richness peak at intermediate elevation. McCain and Grytnes (2010) evaluated the history of elevational richness studies and described four main trends in elevational species richness; decreasing species richness with increasing elevation, plateau in low elevation and decreasing with or without mid-elevational peak and a unimodal patterns with a mid-elevational peak. Similarly, Guo *et al.* (2013) compiled and analyzed data from 443 elevational gradients. Their results showed that most elevational diversity curves were positively skewed (maximum diversity below the middle of the gradient) and the elevation of peak in diversity increased with the elevation of lower sampling limits and to a lesser extent with upper limit.

Studies on elevational gradient analysis in various regions revealed different distribution trends and driving factors and hypothesis. Brown (2001) concluded that distribution and diversity of small mammals in elevational gradients on mountains in the Philippines, Borneo, southern Maxico and western United State were influenced by ecological factors such as climate, productivity and habitat heterogeneity and evolutionary factors such as dispersal, extinction and speciation events. Clausnitzer and Kito (2001); Denys *et al*. (2009); Caceres *et al*. (2011a) and Garshong *et al*. (2013) reported that vegetation types and microhabitat complexity may play a crucial role in structuring small mammal assemblages. McCain (2004) tested mid-domain, climatic and community overlap hypotheses for tropical elevational gradient of small mammals in north-eastern region of Costa Rica and reported both alpha and gamma species richness peaked at mid-elevation. But geometric constrains and climatic conditions became important predictors. Mulungu *et al*. (2008) and Mena and Medellin (2017) analyzed small mammal diversity along altitudinal gradients and argued that non-volant small mammals diversity increased with habitat complexity and heterogeneity. Bateman *et al.* (2010) found a positive non-linear relationship between altitude and small mammal species richness in north-eastern Australia. And they claimed that a peak in species richness occurred at the point of optimal environmental conditions and greatest vegetation juxtaposition. Krystufek *et al.* (2010) observed steady decline in species richness of small mammals on Mt. Pohorje, Slovenia and the observed trend was due to primary productivity. Gardner *et al.* (2011) also claimed that small mammal diversity was strong positively correlated to understory plant biomass, temperature and precipitation. Krystufek *et al*. (2011) observed hump shaped pattern proved by mid-domain effect. Novillo and Ojeda (2011 and 2014) found hump shaped and positive monotonic relationship of small mammal species richness and altitude in South Central Dry Andes. They argued that climate and topography were the most important predictor variables explaining small mammal species richness and abundance patterns. Wu *et al*. (2013) obtained hump shaped species richness pattern for non-volant small mammals along altitudinal gradients on Gongga Mountain in China. They concluded that temperature, precipitation, plant species richness and mid-domain effect were significant in explaining species richness patterns. Andrade and Monjeau (2014) noted hump shaped pattern of small mammal species richness in Argentine Patagonia controlled by temperature as a main factor. Stanley *et al*. (2014) found mid-elevational peak of diversity of small mammals along altitudinal gradients on Mt. Kilimanjaro. They found significantly negative correlation between elevation and shrew species diversity but no correlation of rodent with altitude. Stanley and Kihaule (2016) found mid-elevational peak of small mammal diversity and rainfall positively influenced trap success rates for shrew but not for rodent on the southeastern versant of Mt. Meru. Chen *et al.* (2017) obtained hump shaped patterns with different diversity curves along elevational gradients on both western and eastern slope of the Ailao Mountain, Southwest China. And they concluded that area and productivity were the most important factors in explaining the variation of total species richness of small mammals. Shuai (2017) investigated the elevational distribution of rodent and underlying mechanisms along the southern and northern slopes of Mt. Taibai in China. The species richness of rodent on the two slopes showed distinct patterns with a monotonically decreasing pattern along the southern slope and hump shaped pattern along northern slope. Temperature and mid-domain effect were considered as the most important explanatory factors along southern and northern slope respectively.

2.2 Small mammal diversity in Nepal

The studies of mammals of Nepal were started by Hodgson (1832) (Thapa, 2014). Scully (1887) described 19 species of bats. Hinton (1922) distinguished *Soriculus nigrescens* subspecies. Biswas and Khajuria (1955) reported two species *Ochotona angdawai* and *Alticola bhatnagari*. Martens and Niethammer (1972) recorded a new species *Apodemus sylvaticus wardi*. Mitchell and Punzo (1975) described a new species *Ochotona lama*. Mitchell (1978) described six species of pica. Ingles *et al*. (1980) reported the first record of *Diomys crumpi* and record of other three shrews. Abe (1982) conducted a faunal survey on small mammals in Central Nepal and recorded 32 different species of small mammals in 1968. Oliver (1985) reported the presence of *Caprolagus hispidus* in Chitwan National park, Bardia National park and Suklaphanta Wildlife reservoir. Newton *et al.* (1990) described the collection of 71 specimens of 11 species of Muridae and Soricidae from nine localities in Nepal collected by the University of East Anglia Expedition to Nepal. Kock (1996) discussed a collection of 10 species of Chiroptera. Mekada *et al*. (2001) conducted a faunal survey and collected 131 specimens of insectivores and rodents from the Annapurna region and outskirts of Kathmandu. Adhikari (2001) did a comprehensive study of small mammal diversity of the Western

Terai. Nembang (2003) studied about status and distribution of small mammals in Shuklaphanta Wildlife Reserve. His study reported 12 species of small mammals including eight rodents, two shrews, one carnivore and one lagomorph. The abundance and distribution were correlated with percentage cover of ground vegetation with patchy and random distribution pattern. Dahal *et al*. (2011) conducted survey of small mammals in Chitwan National Park and recorded 12 species. They recorded only two species of Muridae and one species of Scuridae during their survey. Pearch (2011) conducted literature survey to review of biological diversity and distribution of small mammals taxa throughout the ten terrestrial ecoregion and the sixteen principal protected areas of Nepal. One hundred and eighteen species of small mammals representing the order Chiroptera, Scandentia, Lagomorpha, Soricomorpha and Rodintia were acknowledged to occur in Nepal. Pandey and Kaspal (2011) conducted the survey of small mammals to know their distribution and diversity in Koshi Tappu Wildlife Reserve by camera trapping method. Five species of small mammals belonging to five genera and four families were recorded. Adhikari (2013) did a research to assess abundance and distribution of small mammals in riverine and Sal forest of Chitwan National Park and reported 14 species of small mammals belonging to three order and six families. The abundance of small mammals was found higher in riverine forest than in Sal forest. Similarly the distribution pattern was clumped in studied area.

2.3 Comparison of traps efficiencies

Many researchers have compared the efficiencies of small mammal trapping methods and found great variations among trap types and small mammal taxa. Filho *et al*. (2006) compared efficiencies of Tomahawk, Sherman, Snap and Pitfall traps. Where Sherman traps captured a significantly greater abundance of individuals and higher species richness than the other three types of trap. Nicolas and Colyn (2006) compared the efficiencies of three types of traps for sampling small mammals and concluded that pitfall traps were more efficient than baited traps for capturing shrews but were less efficient for capturing rodents. Sherman traps are more effective for trapping smaller rodent species while snap traps tend to be more effective for trapping larger ones. Belant and Windels (2007) compared the efficiency of Victor Tin Cat and Sherman live traps for capturing small mammals and concluded greater overall mean capture rates for Sherman traps than for Tin Cat traps capture. They found greater species diversity values for Sherman traps in both habitats. Then they concluded that in sampling arrays tested, Victor Tin Cat traps were less effective than Sherman traps for estimating small mammal abundance and diversity. Dizney *et al*. (2008) compared capture rates of three traps and found that pitfalls were the most effective trap, followed by Sherman traps with Mesh traps as a very distant third. Sherman traps significantly outperformed Mesh traps overall when compared for larger species that were not contained by pitfall traps. Pitfall traps having the highest measures for small mammals, and a combination of Sherman and Pitfall traps having the highest measure when considering both larger and smaller mammals. Torre *et al.* (2010) investigated trap efficiency and specificity of three widely used live trapping methods (Sherman, Mesh and Pitfall traps) in an agricultural landscape of NE Spain.

Where Sherman traps yielded more species than Mesh and Pitfall traps. Caceres *et al*. (2011b) compare the efficacy of different trapping methods for sampling small mammals, consisting of trap type (Pitfall, Sherman, and Wire traps) and position (ground and understory) in the Cerrado biome of Brazil. The comparison between Sherman and Wire traps indicated no significant difference, although abundance has been higher for wire cages. And their study confirmed the high success rate for pitfall traps and combinations of trapping methodologies for surveying mammalian diversity. Alm *et al*. (2014) compared the efficiencies of the capture of small mammals in Sherman traps and Pitfall traps and Pitfall traps were found to be more effective for sampling.

3. MATERIALS AND METHODS

3.1 Study area

A mountain of Shivapuri Rural Municipality – 1, Nuwakot, Nepal in northern side of Shivapuri hill was chosen as the study area of research topic "Distribution of small mammals along altitudinal gradients in the mid-mountain of Nuwakot, Nepal". The southern slope lies between 27º 51' 4" and 27º 52' 39" N latitudes and 85º 25' 21" and 85º 25' 55" E longitudes. The elevation ranges from about 1,190 m to 2,478 m above sea level.

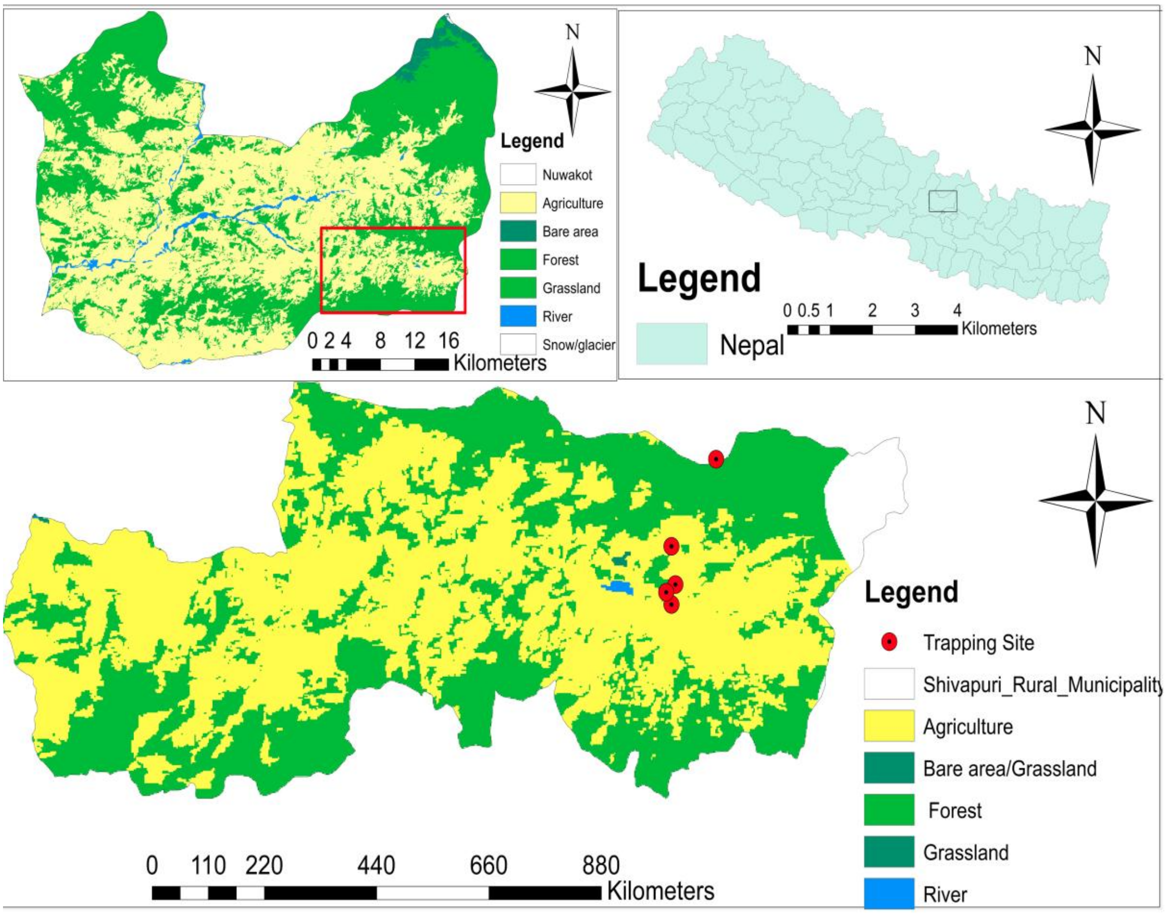

Figure 2: Map of study area.

3.1.1 Climate

The climate ranges from warm temperate at lower portion to cold temperate at upper portion. The higher peak receives occasional snow whereas some lower parts receive occasional frost in winter. The minimum and maximum temperatures throughout the year range from 3ºC and 23ºC in January to 19ºC and 32ºC in June respectively. Similarly the average temperature ranges from 15ºC in January to 28ºC in June (Figure 3). During the study period the minimum and maximum temperature ranged from 9ºC to 22ºC and

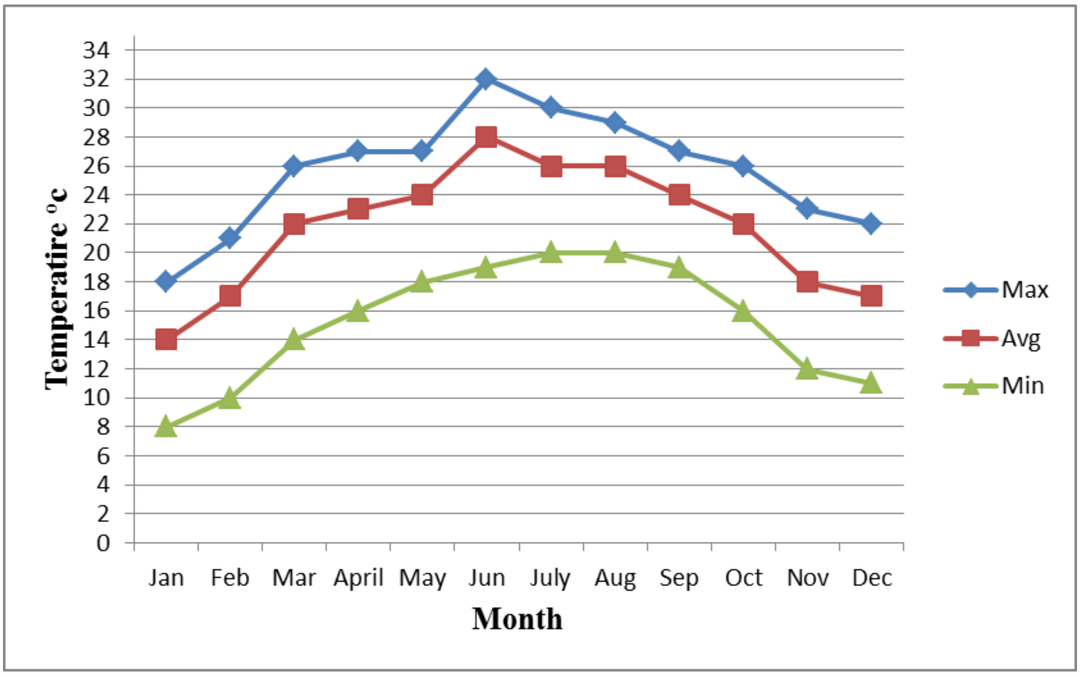

Figure 3: Monthly temperature recorded at Meteriological station at Kakani (2016) (DHM Government of Nepal).

from 25°C to 33°C respectively. Major portion of annual rainfall is occupied by monsoon rain and in other season the rainfall is almost absent. The maximum rainfall of 934.9 mm occurred in August and the minimum rainfall was of 3.8 mm in November (Figure 4).

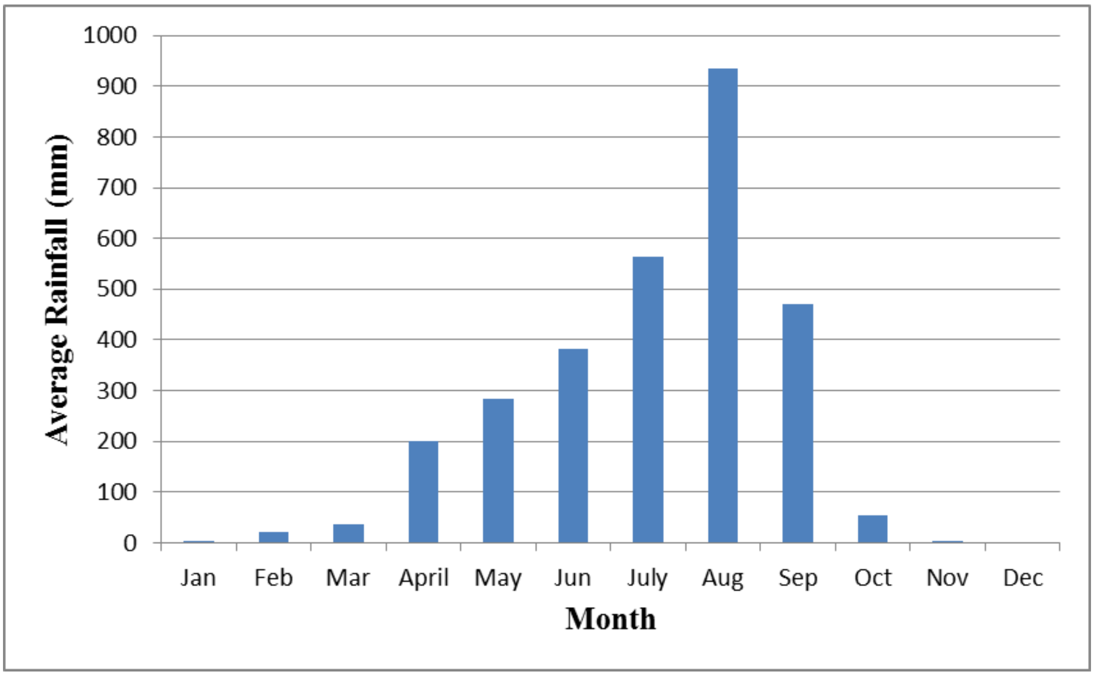

Figure 4: Monthly average rainfall recorded at Meteriological station at Kakani (2016) (DHM Government of Nepal).

3.1.2 Flora and Fauna

The mountain is very rich in biodiversity, which harbors numerous floral and faunal species but their systematic studies are still in wait. Diverse species of vegetation, mammals, birds, reptiles and amphibians are commonly encountered. Similarly innumerate species of invertebrates are seen in these landscapes. The forests belong to upper temperate broadleaved and upper temperate mixed broadleaved types. General vegetation includes Nepalese Alder (*Alnus nepalensis*), Schima (*Schima wallichii*), Meda (*Lisea monopetala*), Chirpine (*Pinus roxberghi*), Indian Chestnut (*Castanopsis indica*), Tree Rhododendron (*Rododendron arboretum*), Sour Cherry (*Prunus cerosoides*), Layered Acorn Oak (*Quercus lamelosa*), Kaphal (*Myrica esculenta*), Chinese Sumac (*Rhus javanica*), Drue (*Lyonia ovalifolia*), Oak (*Quercus* sp.), etc. Commonly visible mammalian species are Rhesus Monkey (*Macaca mulatta*), Grey Langur (*Semnopithecus schistaceus*), Wild Boar (*Sus scrofa*), Barking Deer (*Muntiacus vaginalis*), Sumatran Serow (*Carpicornis sumatraensis),* Goral (*Naemorhedus goral*), Himalayan Black Bear (*Ursus thibetanus*), Moongose, Leopard (*Panthera pardu*), Leopard Cat (*Prionailurus bengalensis*), Jungle Cat (*Felis chaus*) and many species of rodents and shrews.

3.1.3 Socio-economics status

Majority of people consists of Tamang and Gurung Community in higher altitude and Chherti in lower altitude. Only lower and middle region of the mountain were occupied by human settlement area and other regions were covered by forested area, grassy area and cultivated land. The economic status of families was low to middle class. Their main sources of income are farming and domestic animals. Rice, maize, wheat and millet were main crops for lower region and maize, millet and potato were main crops for upper region people. The important domestic animals were buffalo, cows and goats.

3.2 Sampling design and data collection

3.2.1 Sampling design

Five trapping sites denoted as Site 1, Site 2, Site 3, Site 4 and Site 5 were selected along the human trail of mountain from riverine base to top of mountain with elevational midpoint of altitude 1,200 m, 1,500 m, 1,800 m, 2,100 m and 2,400 m respectively. At each altitudinal gradient, two trapping grids of 50 m × 50 m were formed 5-10 m away from elevation midpoint in both sides of the human trail. Each trapping grid constituted three horizontal trapping lines separated by 25 m.

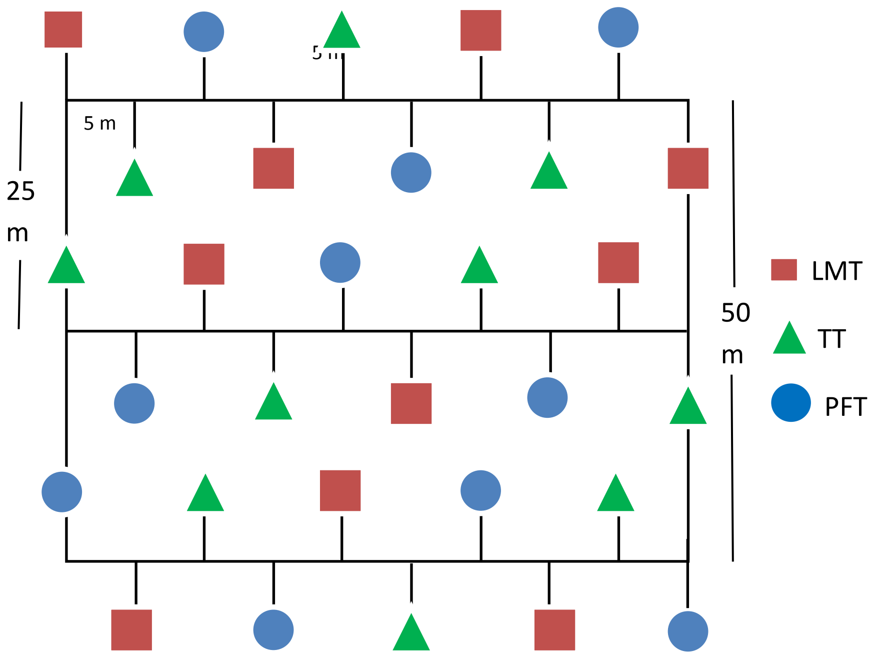

Figure 5: Arrangement of three types of trap in a trapping grid.

Ten trapping stations on each trapping lines separated by 5 m and distanced 5 m above and below the trapping line with alternative arrangement and trap type were installed (Figure 5).

For the assessment of dominant vegetation species, four quadrates for each vegetation category, of 20 m × 20 m for trees, 10 m × 10 m for shrubs and 1 m × 1 m for herbs were used (Annex 3). Four quadrates were laid along four directions about 5-10 m away from elevational central point of each trapping sites. Dominant vegetation species were termed for those species with the highest abundance at all four quadrates. Similarly the scientific name of dominant trees, shrubs and herbs were obtained with the help of DFRS (2014 and 2015).

3.2.2 Trap Used

For sampling of small mammals, live trapping methods were applied. Three types of live traps, naming Local Mesh Trap (LMT), Tube Trap (TT) and Pitfall Trap (PFT) were used for trapping purposes. As LMT, rectangular silver white colored metal wire mesh boxes (21.5 cm × 10.3 cm × 10.3 cm) with trapping mechanism were used. BioEcoss tube trap by Siman Poulton were used as Tube Trap (TT). And blue colored plastic buckets (upper perimeter 68 cm, lower perimeter 57 cm and salient height 20.3 cm) were used for PFT (Photo 1). In total thirty live traps, ten of each type was installed in each trapping altitudes for six days.

Local Mesh Trap Tube Trap Pit Fall Trap

Photo 1: Three types of trap used for sampling of small mammals.

3.2.3 Trapping sites

Site 1: The center point was located at 27^{o} 51'4" N, 85^{o} 25' 21" and 1,198 m above sea level. It was considered as trapping site at 1,200 m altitude. Average max and min temperature during trapping period were 20.5^{o}C and 31.5^{o}C respectively. Moist riverbank, high conopy *Alnus* forest, highly irrigated rice field and uncultivated land were major habitat. Major trees, shrubs and herbs were Nepalese alder (*Alnus nepalensis*), Schima (*Schima wallichii*), Meda (*Lisea monopetala*), Golden Himalayan Raspberry (*Rubus ellipticu*), Barberry (*Berberis sp*), Indian Squirrel Tail (*Colebrookea* sp.), Chainese Chaste Tree (*Vitex negunta*), Himalayan Nettle (*Girardinia diversifolia*), Asian Melastome (*Melastoma* sp.), Cateweed (*Eupatorium acuminatam*), Stalkless Elatostema (*Elatoatema sessile*), Mugwort (*Artemisia* sp.), Chaff-flower (*Achyranthes aspera*), Tuber Ladder Fern (*Nephrolepsis elliptica*), etc. Cultivated lands consisted of rice crop.

Site 2: The center point was situated at 27^{o} 51' 17" N, 85^{o} 25' 24" E and 1,470 m above sea level. This site was considered as trapping site at 1,500 m altitude. Average min and max temperature during trapping period were 18.6^{o}C and 30.5^{o}C respectively. Pine forest and cultivated area with maize crop was only major habitats. Dominant trees, shrubs and herbs were Chirpine (*Pinus roxburghii*), Dropping Fig (*Ficus semicordata)*, Meda (*Lisea monopetata*), Barberry (*Barberis aristata*), St. John's Wort (*Hypericum uralus*), Golden Himalayan Raspberry (*Rubus ellipticus*), Spanish Dagger (*Yucca gloriosa*), Mugwort (*Artemisia* sp.), Catweed (*Eupatorium acuminatum*), Studel (*Capillipedium assimile*), Scented Grass (*Chrysopogon gryllus*), Satintails Grass (*Imeprata cylindricall*), etc. Cultivated land crop was maize.

Site 3: The center point lied at 27^{o} 51' 42" N, 85^{o} 25' 21" E and 1,789 m above sea level. It was taken as trapping site of 1,800 m altitude. The average min and max temperature during trapping were 18.2^{o}C and 30.2^{o}C. The cultivated area with maize, human settlement, forest and grassland were main types of habitats. The common trees, shrubs and herbs were Nepalese Alder (*Alnus nepalensis*), Tree Rhododendron (*Rododendron* *arboretum*), Schima (*Schima wallichii*), Chirpine (*Pinus roxburghii*), Sour Cherry (*Prunus cerosoides*), Indian Chestnut (*Castanopsis* sp.), Barberry (*Berberis* sp.), St. John's Wort (*Hypericum uralus*), Asian Melastome (*Melastema* sp.), Golden Himalayan Raspberry *(Rubus ellipticus*), Scented Grass (*Chrysopogon gryllus*), Catweed *(Eupatorium acuminatum*), Stalkless Elatostema (*Elatostema sessile*), Scutch Grass (*Cynodon dactylom*), etc. Cultivated land crop was maize.

Site 4: The point at 27° 31' 12" N, 85° 15' 17" E and 2,050 m above sea level was taken as trapping center of 2,100 m altitude. The min and max temperature during sampling were 16°C and 25.6°C. The forest and scattered grassland within forest were main habitats. Trees, shrubs and burbs were Layered Acron Oak (*Quercus lamelosa*), Kafal (*Myrica esculenta*), Jingane (*Eurya acuminate*), Nepalese Alder (*Alnus nepalensis*), Chinese Sumac (*Rhus javanica*), Asian Melastome (*Melastoma* sp.), Barberry (*Berberis* sp.), St. John's Wort (*Hypericum uralum*), Bilauni (*Maesa chisis*), Scented Grass (*Chrysopogon gryllus*), Mug Wart (*Artemisia* sp.), Fern (*Gleichenia gigantean*), Red Grass (*Themeda caudate*), Sabaigrass (*Eulaliopsis binate*), Catweed (*Eupatorium acuminatum*), etc. There was absence of cultivated area.

Site 5: Centre point was made at 27° 52' 39" N, 85˙ 25' 55" E and 2,478 m above sea level and considered as trapping site of 2,400 m altitude. The min and max temperature during sampling were 10.5°C and 26.2°C. The major habitats were *Lyonia* forest, Quercus forest, open land covered by *Gleichenia* and grassland. Trees, shrubs and herbs were Drude (*Lyonia ovalifolia*), Oak (*Quercus* sp.), Schima (*Schima wallichii)*, Nepalese Alder (*Alnus nepalensis*), Asian Melastome (*Melastoma* sp.), Barberry (*Berberis* sp.), Golden Himalayan Raspberry (*Rubus ellipticus*), False Assegai (*Maesa chisis*), Fern (*Gleichenia giganta*), Mugwart (*Artemisia* sp.), Scented Grass (*Chrysopogon gryllus*), Sabaigrass (*Eulaliopsis binate*), Satintails (*Imeprata cylindrical*), Catweed (*Eupatorium acuminatum*), etc. There were no cultivated areas at all.

3.2.4 Data collection, morphometric measurements and species identification

Trapping of small mammals were performed during June to July of 2017. For LMT and TT baiting of mixture of coconut pieces, peanut, maize, wheat, pieces of fried fish and pieces of sweet potatoes were used and red plastic piece with station and trap numbers tied at top of 50 cm bamboo stick was used for numbering and easy finding of trapped station and trap types. Plastic buckets were buried so that upper rum flush with the ground level. A 50 cm high black plastic drift fence of 10 m length was placed over the bucket bisecting the opening. Traps were visited twice a day during 5 am-7 am in the morning and 5 pm -7 pm in the evening. Baits were replaced by new baits in each evening to decrease damage made by arthropods. Daily minimum and maximum temperature were recorded by min-max thermometer.

The number of individuals and species trapped per day were recorded (Annex 1). The trapped animals were transferred in transparent plastic bags and the standard morphometric measurements (head-body length, tail length, ear length, hind and fore feet length and body weight) were recorded (Figure 6) (Annex 2).

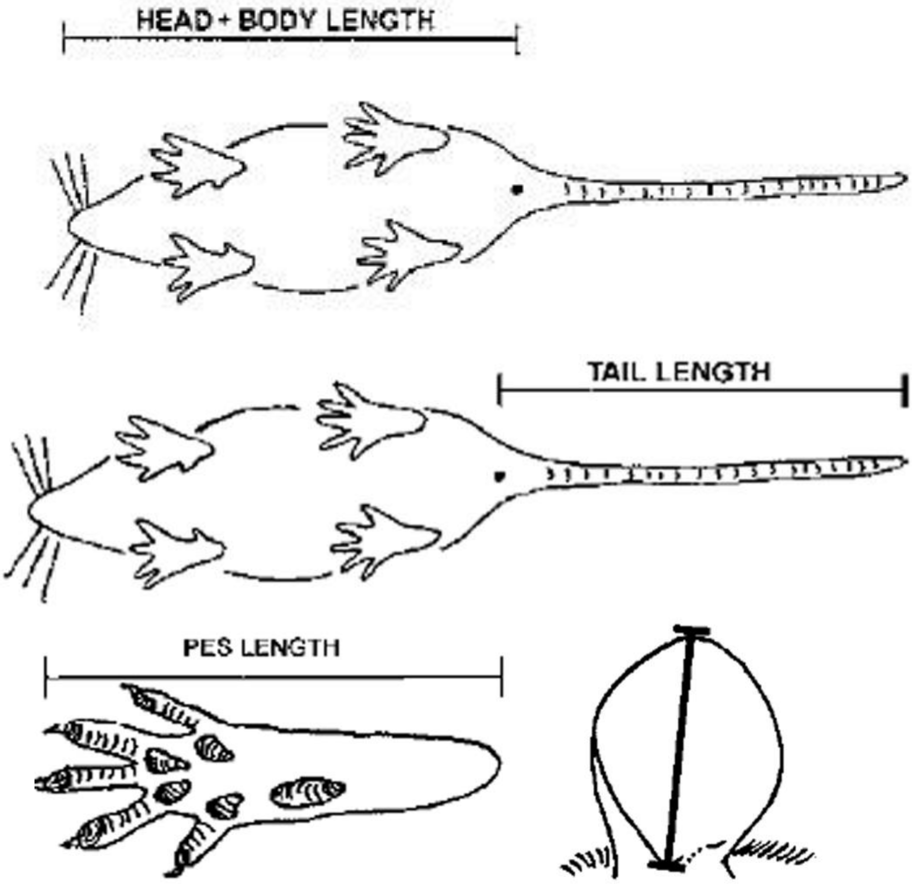

Figure 6: Representation of morphometric measurements of trapped individuals (Aplin *et al*., 2003).

Sex (using ano-genital distance which is longer in male) and reproductive condition of male (scrotal testes as young and abdominal testes as young) and female (perforated vagina as adult and imperforated vagina as young) were recorded. Then caught individuals were marked on toes and finger by permanent colored marker. The caught individuals of small mammals were identified with the help of Shrestha (1997); Lunde and Son (2001); Aplin *et al.* (2003); Baral and Shah (2008); Jnawali *et al*. (2011) then the scientific name of identified species were followed according to IUCN (2017).

3.3 Ecological data analysis

The data were analyzed by calculating relative abundance, diversity index, community evenness, community similarity and β diversity (Species turnover rate) for the assessment of biodiversity along elevational gradient of the mountain landscape and trap success rate for comparison of trap efficiencies (Garshong *et al*., 2013). Species accumulation curve were constructed to verify the completeness of the sampling effort and scatter plot with trend line was used to analyze altitudinal pattern of species diversity of small mammals.

3.3.1 Relative abundance = (N_i/N) ×100%. Where, N_i = total number of individual of each species in all habits, N_t = total number of individuals caught during the entire study.

3.3.2 Diversity index

Diversity index was calculated by using Shannon-Wiener index, $H' = -\sum P_i \ln P_i$, Where The (P_i) refer to the proportion of species i in the sample. This index is species richness weighted.

3.3.3 Community evenness $J' = H'/H_{max.}$ Where H_{max} = lnS (s is total number of different species). It focuses on how evenly the species are distributed in the community.

3.3.4 Community similarity and β diversity (Species turnover rate): Community similarity was calculated by Sorensen similarity index, $S_S = 2a / (2a + b + c)$ where S_S = Sorensen's similarity index, a = number of species common to the both sites, b = number of species unique to the first site and c = number of species unique to second site. β diversity (Species turnover rate) is also based on presence absence data of two sites and calculated through the following equations:- $\beta = S / \alpha - 1$, again $S = a + b + c$ and $\alpha = (2a + b + c) / 2$ then $\beta = (b + c) / (2a + b + c)$ which is Sorensen dissimilarity and it can be found for all sites using vegdist function of vegan package of R-studio.

3.3.5 Trap success = (N_j / T_n) ×100%. Where, N_j = total number of trap individual and T_n =total number of trap nights. The TS tells how many of traps set at a site were able to capture the target species.

3.4 Statistical analysis

Chi-square goodness-of-fit test for the comparison of trap success rates of five altitudinal gradients, Spearman rank correlation test of species richness, species diversity and trap success rates with altitude, Kruskal Wallis test to compare the means of trapped individuals and trap success rates of five altitudinal gradients and correspondence analysis to analyze and represent association of species to altitude on the basis of site × species abundance data matrix were used for statistical analysis and were calculated by using R-studio software. For correspondence analysis "summary(ca(X)) and plot(ca (X),arrows=c(F,T),ldw=1,col=c("black","black"),col.lab=c("black","black"))" commands were used in ca package of R. Where, X is species × site data matrix. The results were considered statistically significance if p-value were less than 0.05.

4 RESULTS

4.1 Diversity of small mammals along altitudinal gradients

In an effort of 900 trap-nights, 104 individuals of small mammals of ten species of rodents and shrews were captured for an overall trap success of 11.55 % along altitudinal gradient of the mountain. Small mammals of only Muridae family of Rodentia and Soricidae family of Soricomorpha were trapped by three types of trap along altitudinal gradients (Table 1).

Table 1: Captured small mammal species along altitudinal gradients.

Family	Species	
	Common Name	Scientific Name
Muridae	Royle's Mountain Vole	*Alticola roylei* Gray, 1842
	Long Tail Field Mouse	*Apodemus sylvaticus* (Linnaeus, 1758)
	Lesser Bandicoot Rat	*Bandicota bengalensis* (Gray, 1835)
	Farm-colored Mouse	*Mus cervicolor* Hodgson, 1845
	House Mouse	*Mus musculus* Linnaeus, 1758
	Little Himalayan Rat	*Niviventer eha* (Wroughton, 1916)
	Himalayan Field Rat	*Rattus nitidus* (Hodgson, 1845)
	House Rat	*Rattus rattus* (Linnaeus, 1758)
Soricidae	Ling Tailed Mountain Shrew	*Soriculus macrurus* Blandford, 1888
	House Shrew	*Suncus murinus* Linnaeus, 1766

Out of 104 individuals trapped, 97 were rodents including eight species (*Alticola roylei, Apodemus sylvaticus, Bandicota bengalensis, Mus cervicolor, Mus musculus, Niviventer eha, Rattus nitidus, and Rattus rattus*) of family Muridae and seven individuals were shrews comprising two species (*Soriculus macrurus and Suncus murinus*) of family Soricidae (Table 1).

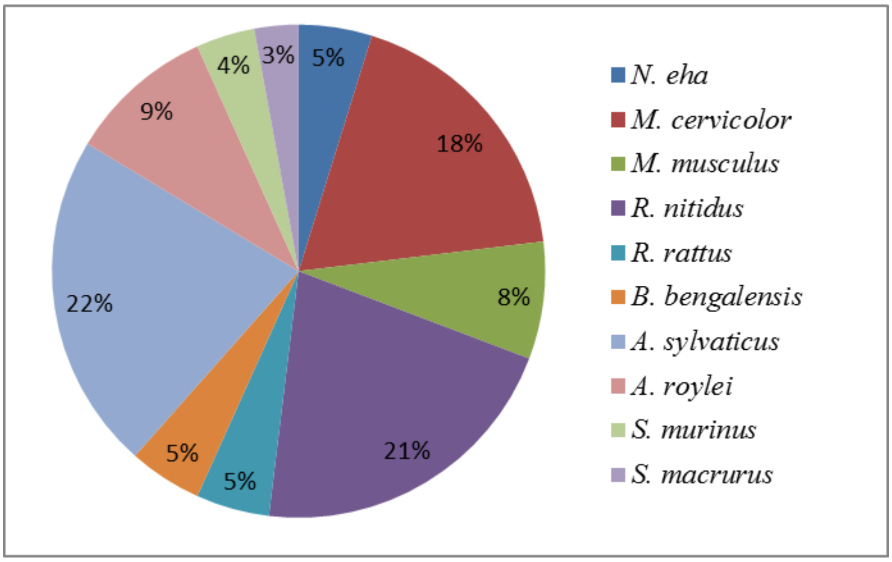

Figure 7: Relative abundances of observed rodent and shrew species (N= 104).

Among ten species of rodent and shrew captured along elevational gradient, *Apodemus sulvaticus* was the most abundant species followed by *Rattus nitidus* and *Mus cervicolor* respectively (Figure 7). On the other hand, *Bandicota bengalensis, Rattus rattus and Niviventer eha* were the least abundant rodent species with same relative abundance of each, captured along altitudinal gradient followed by *Mus musculus*. Shrew species, *Suncus murinus* and *Soruculus macrurus* were the least abundant species with relative abundance of four and three percent respectively.

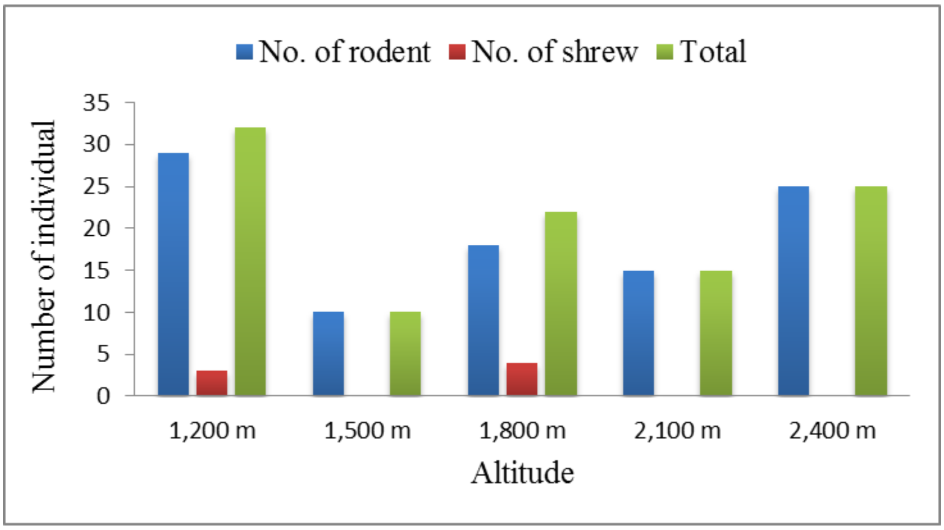

Figure 8: Abundances of rodent and shrew at each altitudinal gradient.

Among five trapping altitudes, comparatively more rodent individuals were trapped at altitude 1,200 m followed by 2,400 m. Similarly, comparatively lesser individuals of rodents were captured at altitude 1,500 m followed by altitude 2,100 m. But shrews with very small numbers of individuals were trapped only at altitude 1,200 m and 1,800 m. Shrews were not caught at other three altitudes during sampling period (Figure 8). The total number of trapped individuals of rodent and shrew were significantly different along altitudinal gradients ($\chi^2 = 14.173$, df = 4, $p < 0.05$).

Table 2: Altitudinal distribution, abundance and diversity of rodent and shrew.

Species	1200 m	1500 m	1800 m	2100 m	2400 m	Total
Niviventer eha	3	2	0	0	0	5
Mus cervicolor	10	0	0	0	9	19
Mus musculus	5	3	0	0	0	8
Rattus nitidus	8	5	6	0	3	22
Rattus rattus	3	0	2	0	0	5
Bandicota bengalensis	0	0	2	3	0	5
Apodemus sylvaticus	0	0	8	8	7	23
Alticola roylei	0	0	0	4	6	10
Suncus murinus	0	0	4	0	0	4
Soriculus macrurus	3	0	0	0	0	3
Total	32	10	22	15	25	104
Shannon diversity index	1.67	1.03	1.47	1.01	1.32	2.06
Shannon equitability	0.93	0.94	0.91	0.92	0.95	0.89

Altitude 1,200 m supported 32 individuals of six species of rodent and shrew with relatively high Shannon diversity index (Table 2). Then the most diversified trapping site was altitude 1,200 m with 32 individuals of six species and Shannon diversity of 1.67. On the other hand, altitude 1,500 m and 2,100 m were comparatively least diversified sites with same species richness and more or less similar Shannon diversity index. The diversity index ranges from 1.01 to 1.67. The diversity indices along altitudinal gradients were not significantly different ($\chi^2 = 0.2486$, df = 4, $p > 0.05$). The community equitabilities of all trapping altitudes were more than 95%.

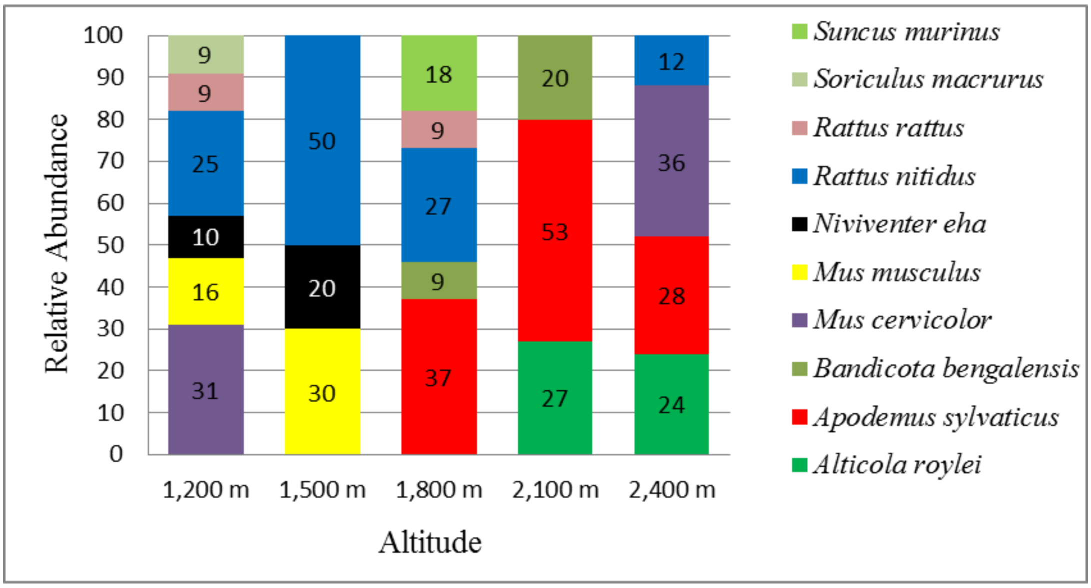

Figure 9: Relative abundance of rodent and shrew species at each altitudinal gradient.

At altitude 1,200 m, *Mus cervicolor* was the most dominant rodent species follower by *Rattus nitidus* (Figure 7). But *Soriculus macrurus* and *Rattus rattus* were rare species with same relative abundance. Among three species sampled at altitude 1,500 m, *Rattus nitidus* and *Niviventer eha* were the most dominant and the rarest rodent species respectively. Similarly, *Apodemus sylvaticus* was the most dominant rodent species at altitude 1,800 m and 2,100 m. Whereas *Bandicota bengalensis* was the rarest rodent species for both altitude 1,800 m and 2,100 m. In the same way, *Mus cervicolor* was dominant rodent species followed by *Apodemus sylvaticus* and *Rattus nitidus* was least abundant rodent species at altitude 2,400 m.

Table 3: Numbers of individuals, trap success rates and species of rodent and shrew sampled in 180 trap night at each altitudinal gradient.

Altitude (m)	Total Individual	% Trap Success	Species	Rodent			Shrew		
				Individual	% Trap Success	Species	Individual	% Trap Success	Species
1200	32	17.78	6	29	16.11	5	3	1.67	1
1500	10	5.56	3	10	5.56	3	0	0.00	0
1800	22	12.22	5	18	10.00	4	4	2.22	1
2100	15	8.33	3	15	8.33	3	0	0.00	0
2400	12	13.89	4	25	13.89	4	0	0.00	0
Total	104	11.56	10	97	10.78	8	7	0.78	2

At altitudes 1,200 m and 1,800 m, both higher number rodent individuals and species were caught than shrew individuals and species (Table 3). But no shrew was trapped at other altitudes. For five trapping sites, the total trap success rates of rodent and shrew varied between 5.56% and 17.78%. Highest trap success rate of 17.78% was observed at altitude 1,200 m whereas the lowest trap success rate of 5.56% was observed at 1,500 m. But the overall trap success rates of five trapping sites were not significantly different ($\chi^2 = 7.873$, df = 4, $p > 0.05$). The trap success rates of shrew at altitude 1,200 m and 1,800 m were very low in comparison of rodent trap success rates. Also total trap success rate of shrew along altitudinal gradient was extremely low than that of rodent trap success rate.

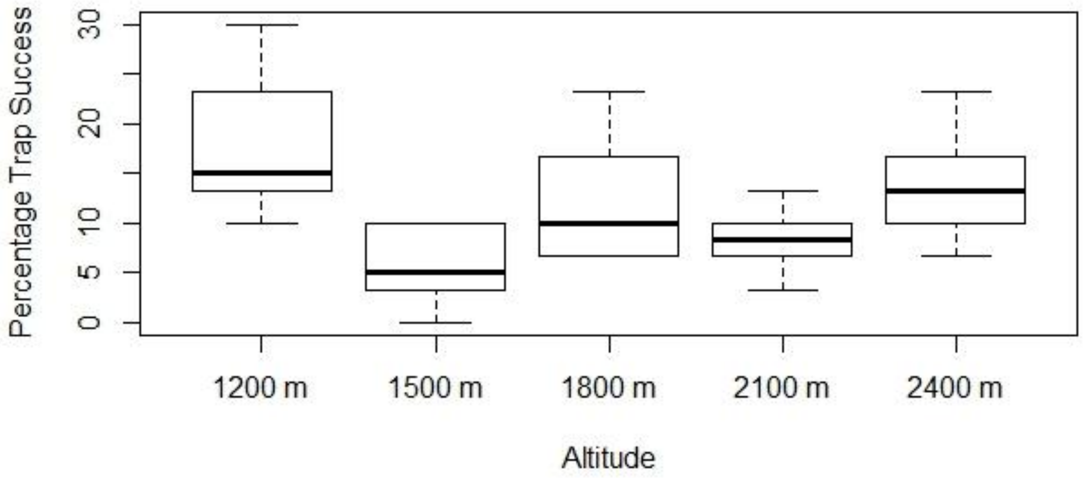

Figure 10: Distribution of daily trap success rates along altitudinal gradients.

Maximum, minimum, first quartile, median and third quartile of trap success rates showed great variation along altitudinal gradients (Figure 10). One way Kruskal-Wallis rank sum test showed significant different in mean trap success rates of five altitudinal gradients (χ^2= 12.442, df= 4 and $p < 0.05$).

4.2 Altitudinal distribution pattern of small mammals

Slightly decreasing trend of species richness and abundance with increase in altitude was observed along altitudinal gradient of the mountain (Figure 11). Both species richness and abundance changed with alternating decreasing and increasing manner with increasing altitude. The highest species richness and abundance was found at altitude 1,200 m. Both species richness and abundance decreased at altitude 1,500 m. Then these values increased at altitude 1,800 m. Again at altitude 2,100 m richness and abundance decreased. Then at altitude 2,400 m, both richness and abundance increased. But the increased value of altitude 1,800 m was lower than that of 1,200 m. Similarly the increased values of richness and abundance of altitude 2,400 m were lower than that of 1,800 m.

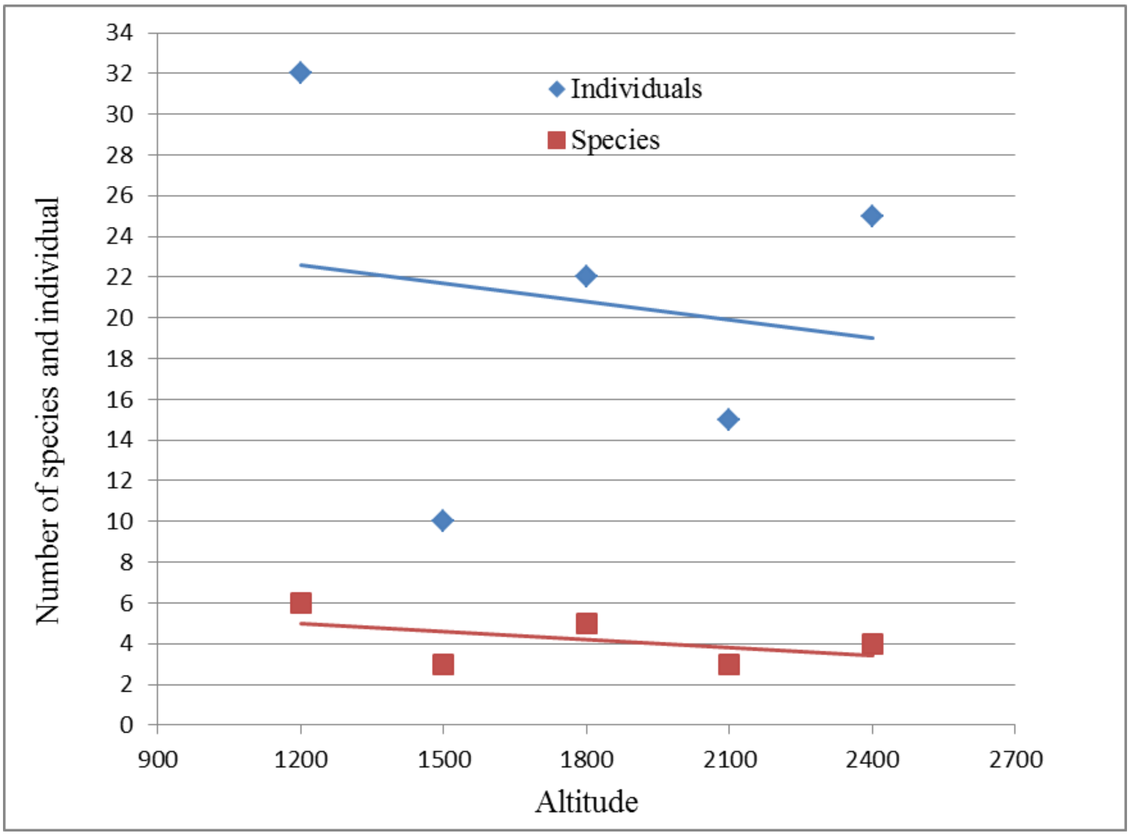

Figure 11: Altitudinal distribution curves of species richness and abundance.

The Spearman rank correlation of species richness and abundance with altitude showed very weak negative relationship. In both cases, the negative relationships were not statistically significant (S = 28.208, $p > 0.05$, r = -0.41 and S = 22, $p > 0.05$, r = -0.1). But trapped individuals and species were highly positively correlated (r =0.87).

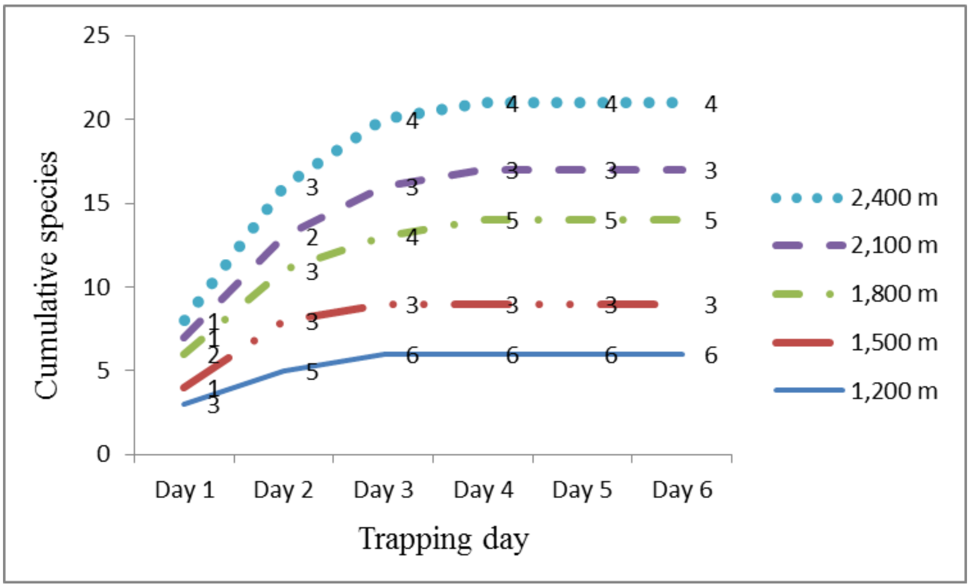

Figure 12: Cumulative species verses consecutive days of small mammals trapping.

Species accumulation curves of all trapping altitudes reached a plateau (Figure 12). For altitude 1,200 m, cumulative species number became constant after third day of trapping with six species. Total three species of rodent were caught with first and second day of trapping at altitude 1,500 m. At altitude 1,800 m the accumulated curve reached a plateau of five species on fourth day of trapping. Similarly, at altitude 2,100 m and 2,400 m, no more new species of rodent were found after third day of trapping with cumulative species number of three and four respectively.

Table 4: Presence absence data of observed small mammal species along altitudinal gradients (1 = presence, 0 = absence).

Species	1200 m	1500 m	1800 m	2100 m	2400 m
Alticola roylei	0	0	0	1	1
Apodemus sylvaticus	0	0	1	1	1
Bandicota bengalensis	0	0	1	1	0
Mus cervicolor	1	0	0	0	1
Mus musculus	1	1	0	0	0
Niviventer eha	1	1	0	0	0
Rattus nitidus	1	1	1	0	1
Rattus rattus	1	0	1	0	0
Soriculus macrurus	1	0	0	0	0
Suncus murinus	0	0	1	0	0

None of the species was found at all altitudinal gradients (Table 4). Most of the species sampled along altitudinal gradients were present at two altitudinal gradients. *Rattus nitidus* was most common species trapped along altitudinal gradient except altitude 2,100 m. Shrew species *Soriculus macrurus* was common only at altitude 1,200 m and *Suncus murinus* was common only at altitude 1,800 m. Rodent species *Niviventer eha* and *Mus musculus* were common for lower gradient, whereas *Alticola roylei* and *Apodemus sylvaticus* were common for upper gradient.

Table 5: Sorenson similarity index between altitudinal gradients.

Altitude (m)	Index	Percentage Similarities
1200 and 1500	0.67	66.67
1200 and 1800	0.18	18.18
1200 and 2100	0.00	0.00
1200 and 2400	0.40	40.00
1500 and 1800	0.25	25.00
1500 and 2100	0.00	0.00
1500 and 2400	0.28	28.57
1800 and 2100	0.50	50.00
1800 and 2400	0.44	44.44
2100 and 2400	0.57	57.14

The community similarity between two altitudinal gradients ranged from zero percent to 66.67 %. Altitude 1,200 m and 1,500 m were the most similar among other followed by 2,100 m and 2,400 m (Table 5). Whereas altitude 1,200 m and 2,100 m and 1,500 m and 2,100 m were totally different form each other for observed rodent and shrew community.

Table 6: Pair wise and overall β diversity (species turnover rate) along altitudinal gradients.

Altitude	1200 m	1500 m	1800 m	2100 m
1500 m	0.33			
1800 m	0.64	0.75		
2100 m	1.00	1.00	0.50	
2400 m	0.60	0.71	0.56	0.43
Overall β diversity along altitudinal gradient			0.65	

Overall species turnover rate along altitudinal gradients was quite high (Table 6). Between two altitudinal gradients, turnover rate between altitude 1,200 m and 2,100 m and 1,500 m and 2,100 m were almost cent percent. The lowest turnover rate was observed between altitude 1,200 m and 1,500 m followed by 2,100 m and 2,400 m. Sorenson similarity and species turnover rate are reverse to each other. As a result, those altitudes with high similarity had less turnover rate and vice versa.

Table 7: Summary of correspondence analysis of site species abundance data matrix.

Principal inertias (eigenvalues):

```
dim    value      %   cum%   scree plot
1      0.613140  53.4  53.4  *************
2      0.317963  27.7  81.0  *******
3      0.148297  12.9  93.9  ***
4      0.069714   6.1 100.0  **
-------- -----
Total: 1.149114 100.0
Plot detail section of rows:
          name   mass  qlt  inr     k=1 cor ctr     k=2 cor ctr
1 |N. eha        |  48  777   77 | -1183 763 110 |  -159  14   4 |
2 |M. cervicolor |  183  775  133 |  -352 148  37 |   723 627 300 |
3 |M. musculus   |   77  810  116 | -1177 799 174 |  -133  10   4 |
4 |R. nitidus    |  212  864   73 |  -468 553  76 |  -351 311  82 |
5 |R. rattus     |   48  430   39 |  -401 174  13 |  -488 257  36 |
6 |B. bengalensis|   48  712   94 |  1168 605 107 |  -491 107  36 |
7 |A. sylvaticus |  221  996  153 |   886 986 283 |   -91  10   6 |
8 |A. roylei     |   96  935  134 |   887 490 123 |   846 446 216 |
9 |S. murinus    |   38  787  125 |   613 101  24 | -1599 686 309 |
10|S. macrurus   |   29  544   56 | -1077 515  55 |   253  29   6 |
```

Plot detail section of columns:

	name	mass	qlt	inr	k=1	cor	ctr	k=2	cor	ctr
1	1200	308	894	219	-843	869	357	143	25	20
2	1500	96	594	183	-1052	507	173	-438	88	58
3	1800	212	905	212	480	200	79	-902	705	541
4	2100	144	791	233	1204	780	341	140	11	9
5	2400	240	847	153	355	173	50	702	674	372

The two dimensional representation of site species data accumulated 81 % of variation of original multidimensional data (Table 7). *Apodemus sylvaticus* contributed more to first dimension followed by *Mus musculus*. Similarly least contribution was shown by *Rattus rattus* trailed by *Suncus murinus*. For second dimension, *Suncus murinus* contributed more followed by *Mus cervicolor*. And *Mus musculus* and *Apodemus sylvaticus* contributed lesser than other species. The quality of species profile showed that about more than 70% variation of species profile except *Rattus rattus* and *Soriculus macrurus* were reproduced by two dimensional subspace. *Apodemus sylvaticus* was strongly correlated with first dimension followed by *Mus musculus and Niviventer eha*, but weakly correlated with second dimension. Similarly, *Suncus murinus and Mus cervicolor* were weakly correlated with first dimension, but strongly correlated with second dimension.

Plot detail section of columns showed that altitude 1,200 m and 2,100 m contributed more for first dimension and less for second dimension. Similarly, altitude 1,800 m and 2,400 m contributed more for second dimension but less contribution for first dimension. Altitude 1,200 m followed by 2,100 m was strongly correlated with first dimension but less for second dimension. In the same way, altitude 1,800 m and 2,400 m were much more represented by second dimension but much less by first dimension. Almost more than 80% variations of altitudes except altitude of 1,500 m were reproduced by those first and second dimensions.

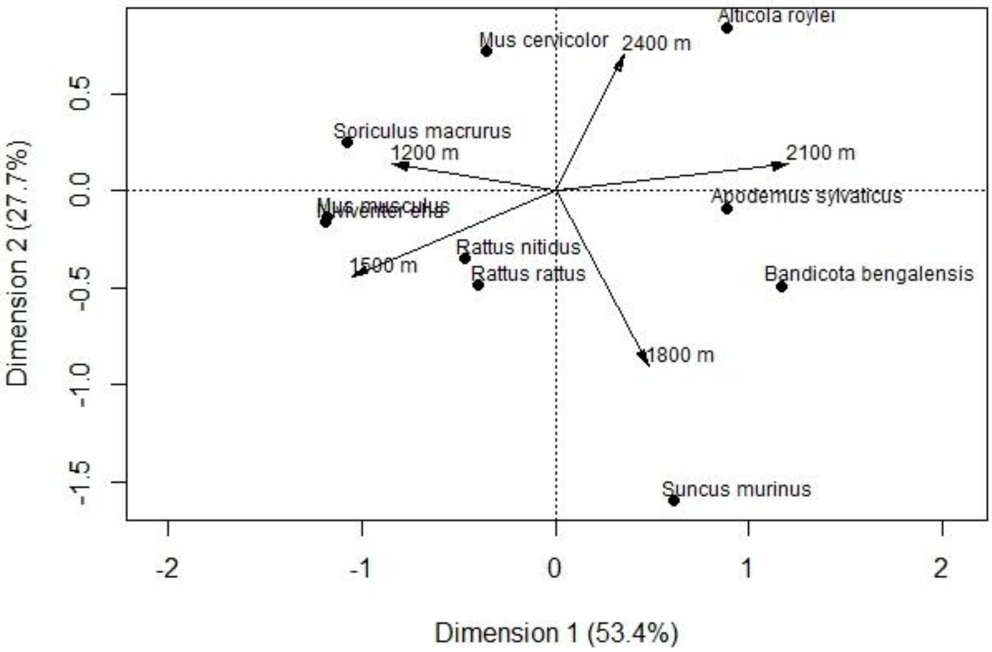

Figure 13: Correspondence analysis biplot of site species abundance data matrix.

The correspondence analysis biplot (Figure 13) depicted that many rodent and shrew species were associated to particular altitudes. The small mammal community of altitude 1,200 m and 1,500 m were more similar to each other than other three sites. Similarly the altitude 1,800 m, 2,100 m and 2,400 m were more similar to each other than 1,200 m and 1,500 m. Rodent species, *Mus musculus, Niviventer eha*, *Rattus nitidus* and *Rattus rattus* were strongly related to altitude 1,200 m 1,500 m. Similarly, *Alticola roylei*, *Apodemus sylvaticus* and *Bandicota bengalensis* were highly related to 1,800 m, 2,100 m and 2,400 m altitude. The two shrew species *Suncus murinus* and *Soriculus macrurus* were only related to altitude 1,800 m and 1,200 m respectively. *Mus cercicolor* was related to 1,200 m and 2,400 m altitude. The biplot of the correspondence analysis displays a quite good separation between all habitats

4.3 Comparison of trap efficiencies

Among three types of traps used for sampling small mammals, Local Mesh Trap trapped more individuals than other trap type (Table 8). Pitfall Trap caught comparatively low individuals and its trap success rate was lowest than other two types. The total individuals trapped by three traps were significantly different (χ^2 = 15.303, df = 2 and $p < 0.05$). Similarly, Local Mesh Trap also trapped more species than other trap types.

Table 8: Total numbers of individuals and species caught by three trap types at five altitudinal gradients (R = Rodent and S = Shrew).

Altitude (m)	Local Mesh Trap			Tube Trap			Pitfall Trap		
	Individual	Species		Individual	Species		Individual	Species	
		R	S		R	S		R	S
1200	16	4		11	3		5	1	1
1500	4	2		4	2		2	1	
1800	10	3	1	9	1	1	3	1	1
2100	6	2		7	2		2	1	
2400	10	3		11	3		4	3	
Total	46	7		42	6		16	6	
Trap night	300			300			300		
Trap success	15.33%			14.00%			5.33%		

The Local Mesh Trap captured rodent and shrew with high trapping efficiency than other trap types. On the other hand, Pit Fall Trap captured the fewest number of individuals with relatively low efficiency. But the variation of trap success rates of three trap types were not statistically significant (χ^2 = 5.105, df = 2 and p > 0.05). All trap types capture more individuals at altitude 1,200 m than other altitudes.

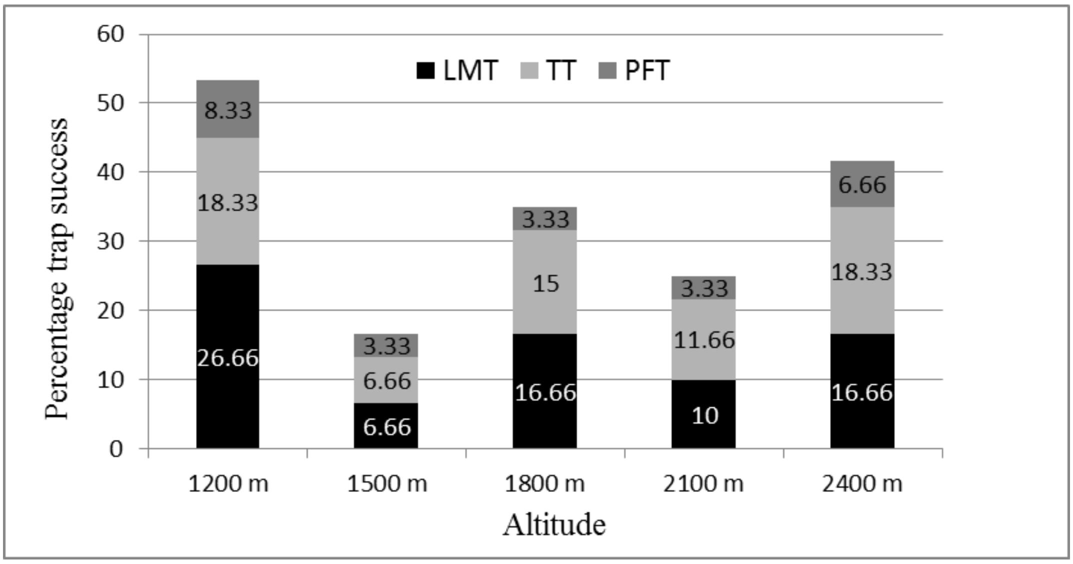

Figure 14: Trap success rates of each trap type at each altitudinal gradient.

At altitude 1,200 m, the trap success rate of Local Mesh Trap was higher than that of Tube Trap and Pitfall Trap (Figure 14). The trap success rate of Pitfall Trap was comparatively low. The trap success rates of three trap types were significantly different at altitude 1,200 m (χ^2 = 9.478, df = 2, p < 0.05). At altitude 1,500 m both Local Mesh Trap and Tube Trap performed with same efficiency. Whereas Pitfall Trap performed less efficiently than others. Similarly, at altitude 1,800 m Local Mesh Trap trapped small mammals with more efficiency than other. The differences among trap success rates were statistically significant ($\chi^2 = 6.5115$, df = 2, $p < 0.05$). But at altitude 2,100 m and 2,400 m, Tube Trap performed with more efficiency than other trap types. At all altitudes, Pitfall Trap performed with less efficiency than other traps.

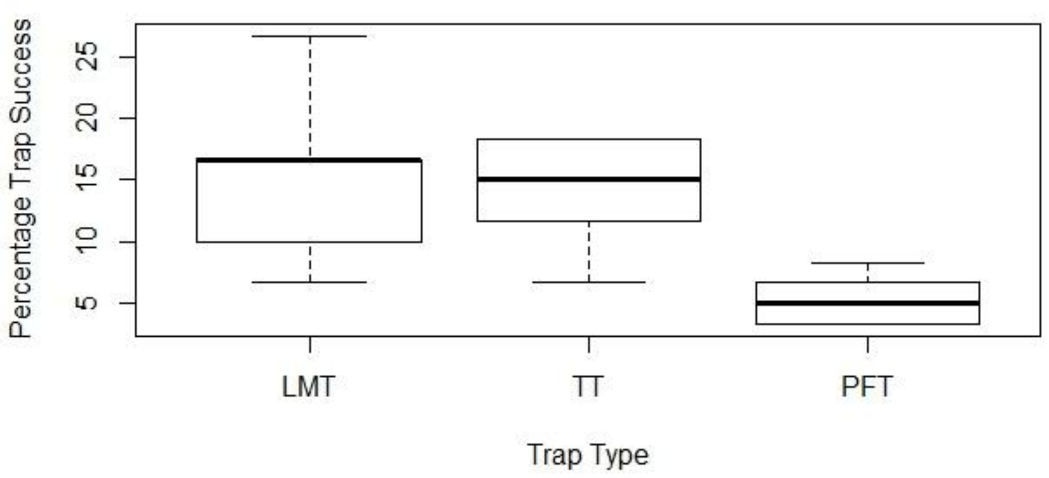

Figure 15: Distribution of trap success rates of three trap types along altitudinal gradients.

The ranges, medians, first quartile and third quartile values of trap success rates of three trap types at five trapping altitudes showed much more variation (Figure 13). One maximum and one minimum outlier value was seen for LMT and PFT respectively. Kruskal-Wallis rank sum test of mean trap success rates of three trapping methods at five altitudes showed that mean trap successes of three live traps were significantly different ($\chi^2 = 7.453$, df= 2 and p= 0.024).

Table 9: Average morphometric measurements of recorded rodent and shrew species.

Species	Weight (gm)	Head body length (cm)	Tail length (cm)
Alticola roylei	72.50	12.59	11.45
Apodemus sylvaticus	20.80	7.67	7.91
Bandicota bengalensis	270.00	22.00	19.80
Mus cervicolor	41.42	10.86	13.22
Mus musculus	21.00	7.43	7.43
Niviventer eha	73.00	12.50	13.90
Rattus nitidus	118.50	16.92	19.10
Rattus rattus	148.00	17.80	11.20
Soriculus macrurus	17.33	7.66	6.43
Suncus murinus	58.25	13.37	7.50

On the basis of comparison of average morphometric measurements among captured species, *Bandicota bengalensis* was the biggest murid rodent species (Table 9). On the other hand, *Mus musculus*, *Apodemus sylvaticus* and *Soriculus macrurus* were the smallest rodent and shrew species captured along altitudinal gradient. *Rattus rattus*,

Rattus nitidus, *Alticola roylei* and *Niviventer eha* were bigger sized rodent species. Similarly, *Mus cervicolor* and *Suncus murinus* were smaller rodent and shrew species.

Table 10: Number of individuals of different species trapped by using three trap types.

Species	LMT	TT	PFT	Total
Alticola roylei	7	2	1	10
Apodemus sylvaticus	-	18	5	23
Bandicota bengalensis	5	-	-	5
Mus cervicolor	7	8	4	19
Mus musculus	-	8	-	8
Niviventer eha	3	2	-	5
Rattus nitidus	18	-	2	20
Rattus rattus	7	-	-	7
Soriculus macrurus	-	-	3	3
Suncus murinus	1	2	1	4
Total	46	42	16	104

Out of ten species sampled along altitudinal gradients, Local mesh trap (LMT) captured seven species (Table 10). Both Tube trap (TT) and Pitfall trap (PFT) captured six species. *Bandicota bengalensis* and *Rattus rattus* were captured only by LMT. Whereas *Mus musculus* was trapped by only TT. Similarly, *Soriculus macrurus* was only captured by PFT. *Alticola ryolei*, *Mus cervicolor* and *Suncus murinus* were captured by all types of trap.

5. DISCUSSION

5.1 Diversity of rodent and shrew along altitudinal gradients

Ten species of small mammals, eight rodents of family Muridae (*Alticola roylei, Apodemus sylvaticus*, *Bandicota bengalensis*, *Mus cervicolor, Mus musculus*, *Niviventer eha, Rattus nitidus* and *Rattus rattus*) and two shrew of family Soricidae (*Soriculus macrurus and Suncus murinus*) were trapped by three trap types with overall trap success rate of 11.56% along altitudinal gradient (Table 1 and 3). The high value of diversity index (Shannon diversity index = 2.06 and equitability = 0.89) showed more stable small mammal community in the studied mountain landscape (Table 2). It was due to the trapping of small mammals during the highest productive period of the year with higher temperature and precipitation (Figure 3 and 4). The overall abundances of all captured rodents and shrew species along altitudinal gradients were significantly different (χ^2 = 50.04, df = 9 and $p < 0.05$). Among observed species *Apodemus sylvaticus* was captured with more abundance along upper region of altitudinal gradient (Figure 7 and table 2) followed by Rattus nitidus captured at four altitudinal gradients except 2,100 m. Whereas *Bandicota bengalensis, Rattus rattus and Niviventer eha* were captured with least abundance at only two trapping sites each. On the other hand, both shrew species *Suncus murinus* and *Soriculus macrurus* were captured with very less abundance, four and five individuals only at altitude 1,800 m and 1,200 m respectively (Table 3 and Figure 7). Though pitfall traps are considered to be only ideal methods for sampling shrews (Nicolas and Colyn, 2006; Dizney *et al*., 2008; Caceres *et al*., 2011a) the trapping efforts sampled almost very poor shrew diversity. The possible reasons behind observing poor shrew diversity along altitudinal gradients, either might be presence of poor diversity of shrew along altitudinal transect or though there might be presence of higher diversity but due to non-baited pitfall traps and unsuitable baits used in other trap types, the sampling was uncompleted for shrew species.

Result of this study showed variation on the species richness, abundance, total trap success rates and mean trap success rates along altitudinal gradients (Table 4 and Figure 8). These variations on distribution and diversity of small mammals along altitudinal gradients might be due to variations on dominant forest types and microhabitat availability along altitudinal gradients as concluded by Clausnitzer and Kito (2001); Mulungu *et al*. (20080); Denys *et al*. (2009); Caceres *et al*. (2011a); Garshong *et al*. (2013) and so on.

No common species for all altitudinal gradients were found (Table 3 and 4) because all observed species of murid rodents and soricid shrews were more or less habitat specialist. Among murid rodents, *Niviventer eha* was common for altitude 1,200 m and 1,500 m. That was mostly caught in relatively dry bushy type habitat of *Girardinia* and *Bubus*. Such habitats were common at altitude 1,200 m and 1500 m. *Mus cervicolor* was found at altitude 1,200 m and 2,400 m in relatively moist and shadowed and rocky habitats near smaller water body area. Such habitats were common for altitude 1,200 m and 2,400 m. *Mus musculus* was smallest murid rodent observed along lower altitudinal gradient. It was only caught at altitude 1,200 m and 1,500 m in relatively dry open grassy area near cultivated fields. Relatively more individuals of *Mus musculus* were observed at altitude 1,200 m due to more abundance of open grassy area near cultivated area than at altitude 1,500 m. *Rattus nitidus* was common species for all altitudes except 2,100 m. It was commonly caught in many habitat types from high canopy to grassland habitats. The absence of this species at altitude 2,100 m might be due to less microhabitat complexity. *Rattus rattus* was mainly caught in rice cultivated area and human settlement area of altitude 1,200 m and 1,800 m respectively. In the same way, *Bandicota bengalensis* was found only at altitude 1,800 m and 2,100 m. It was caught only in much more bushy habitat without high canopy trees where ground soil was loose and fertile that provide burrowing system and fast growing of vegetative material for food. *Apodemus sylvaticus* was found at upper three altitudes where relatively dry grassland areas were common. It was also smallest among murid rodent which was equivalent to *Mus musculus* of lower altitudinal gradient (Table 9). Similarly, *Alticola roylei* was found only at altitude 2,100 m and 2,400 m in dry bushy rocky area without high canopy trees. Such habitats were commonly found in upper altitudinal gradient of the mountain.

5.2 Altitudinal distribution pattern of small mammals

Mostly observed and described small mammalian diversity patterns; mid-elevational peak along altitudinal gradients (McCain, 2005; McCain and Grytnes, 2010; Krystukek *et al*., 2011; Mu *et al*., 2013; Monjeau, 2014; Stanley *et al*., 2014 etc) was not observed in this study (Figure 11). But weak negative correlation between species diversity and altitude showed slightly decreasing trend in species diversity with increasing altitude but the association was not statistically significant (S = 28.208, $p > 0.05$, $r = -0.41$). The change in dominant forest community and habitats heterogeneity along altitudinal gradients supported great variation in the microhabitats of the particular altitudes, hence such variation accounted for variation in species richness and abundances of rodent and shrew as concluded by Clausnitzer and Kito (2001); Mulungu *et al.* (2008); Denys *et al*. (2009); Caceres *et al*. (2011a) and Garshong *et al*. (2013). But the unusual deviation of observed distribution pattern from the generalized pattern might be due to random distribution of suitable microhabitats, human habitation area and cultivated land area.

The number of individuals and species captured varied with altitude, dominant vegetation types and microhabitat complexity. The forest vegetation structure and habitat structure and availability varied greatly with increasing altitude. Higher diversity of rodent and shrew was observed at altitude 1,200 m (Table 2). This might be due to presence of much more heterogeneous microhabitats such as river bank with stony and vegetated surface, high canopy trees, bushy habitats, open grassland habitat, highly fertile cultivated land and some patches of open grassland and rocky habitats, dead fallen trees (Brown, 2001 and Mena and Medellin, 2017). The altitude 1,800 m was second diversified trapping altitude. Complex and heterogeneous microhabitats include human settlement area with old houses and piles of stones and woods, nearby cultivated area, high canopy forested habitat, bushy habitat and uncultivated field covered with variety of grasses species. All these habitats support high diversified rodent and shrew community. The microhabitats at altitude 2,400 m were less complex than those of 1,200 m and 1,800 m. Similarly the altitude 2,100 m and 1,500 m were relatively less diversified than other three altitudes. The altitude 1,500 m became least diversified site for rodents with only ten individuals of three species. It was due to the high canopy homogenous pine forest trees created less complex habitats, the under story was less developed and there was less bushy area in pine forested habitats for food, shelter and protection from predators. The altitude 2,100 m supported more species diversity than altitude 1,500 m did because the habitats at 2,100 m were more complex than that of 1,500 m. The forest habitat was mixed with many vegetation types, understory was bushier, rocky and grassland habitats were also present at altitude 2,100 m. The results of this study showed that the murid rodent and shrew community diversity was determined by dominant forest and understory vegetation types, complexity and heterogeneity of microhabitats.

Sorensen's similarity index based on presence absence data (Table 4) showed that small mammal communities of altitude 1,200 m and 1,500 m were much more similar followed by altitudes 2,100 m and 2,400 m (Table 5). The more similarity between altitude 1,200 m and 1,500 m was due to presence of more overlap species composition. All those three species found at altitude 1,500 m were common for both altitudes. Similarly for altitudes 2,100 m and 2,400, out of four species, two species were common for both altitudes. So these two altitudes were also more similar than other. The species communities of altitude 1,200 m and 1,500 m were completely different from the species community of altitude 2,100 m because there was no common species at all. The altitude 1,200 m and 1,500 m showed little similarity with altitude 1,800 m due to common *Rattus rattus* and *Rattus nitidus* species. The altitude 1,800 m showed relatively more similarity with altitudes 2,100 m and 2,400 m due to occurrence of *Apodemus sylvaticus* in all three altitudes. Among altitudes 1,200 m and 2,400 m and altitude 1,500 m and 2,400 m, altitudes 1,200 m and 2,400 m were more similar than altitude 1,500 m and 2,400 m due to two common species *Mus cervicolor* and *Rattus nitidus* whereas only *Rattus nitidus* was common for altitude 1,500 m and 2,400 m.

Overall β diversity (species turnover rate) was quite high with value of 0.65 (Table 6), which showed much complex murid rodent and shrew community structure determined by vegetation gradients resulted from altitudinal gradients and habitat complexity and heterogeneity. The Sorensen similarity index and β diversity for two communities were reverse of each other (Table 5 and 6). The more similar community shows less species turnover rates and vice versa. The altitudes 1,200 m and 1,500 m were more similar and hence species turnover for these two altitudes were relatively low. And for altitudes 1,200 m and 2,100 m and altitudes 1,500 m and 2,100 m community, the species turnover rates were almost 100% due to completely difference in their community compositions.

Simple correspondence analysis of site species data better exposed ordination of species and altitudes along with their associations to each other (Table 7 and Figure 13). First two dimensions accounted for 81% of variability of original multidimensional form. For 53.40 % representation of variation by first dimension, the relatively more contributed species were *Apodemus sylvaticus*, *Mus musculus*, *Alticola roylei*, *Neviventer eha*, *Bandicota* *bengalensis* respectively. The correlations of these species with first dimension were also high, so the first dimension of reduced space represented much more variation of such species. Accordingly most correlated species for second dimension were *Suncus murinus, Mus cervicolor, Alticola roylei, Rattus nitidus* etc. The correlations with second dimension were also high, so variations of those species were much more accounted by second dimension of reduced space. The altitudes 1,200 m and 2,100 m contributed more for first dimension followed by altitude 1,500 m. Contrastingly, altitudes 1,800 m and 2,400 m contributed more for second dimension of reduced space. So variations of altitudes 1,200 m and 2,100 m were mostly represented by first dimension and that of altitude 1,800 m and 2,400 m were mostly represented by second dimension.

Correspondence analysis biplot also revealed that *Apodemus sylvaticus, Bandicota bengalensis* and *Alticola roylei* were related to altitudes 1,800 m, 2,100 m and 2,400 m. Because these species were common at upper altitudes of the mountain. *Suncus murinus* was related to only altitude 1,800 m and *Soruculus macrirus* was related to only altitude 1,200 m. *Mus cervicolor* was related to altitude 1,200 m and 2,400 m. And *Niviventer eha, Mus musculus, Rattus nitidus and Rattus rattus* were more related to altitude 1,200 m and 1,500 m than 1,800 m.

5.3 Comparison of trap efficiencies

Different trap types (Local Mesh Trap, Tube Trap and Pitfall Trap) used for small mammals sampling showed great variations in their overall trapped individuals, species, mean trap success rates and overall trap success rates as concluded by Torre *et al*. (2010) and Alm *et al*. (2014) (Figure 14 and 15). In our study significantly more individuals and species were captured by LMT than other two type traps (Table 8). In contrast to Nicolas and Colyn (2006); Dizney *et al*. (2008) and Alm *et al*. (2014), pitfall trap captured with the fewest efficiency. The capture success of pitfall trap probably depends on the size of the trap, the smaller the trap, the higher the probability of escape of larger species that are able to jump or climb. The size of pitfall trap used in our study was relatively small. So this may be the potential explanation of lower sampling efficiency of pitfall trap along altitudinal gradients of the studied mountain. Because the larger rodent species could easily escape and only medium and smaller sized species were caught by pitfall traps. Also the pitfall traps were used without baits so there might be low attraction towards this traps and hence low capture efficiency of pitfall trap.

The body sizes of rodent and shrew trapped by different trap type showed great variations related with size of the trap used. The most of the larger sized rodents and shrews were trapped by LMT due to its larger size for housing larger specimen. Whereas most of smaller sized rodent and shrews were captured by TT and PFT and some small species were only trapped by TT (Table 9 and 10). The rodent and shrew species captured by LMT were *Alticola roylei, Bandicota brngalensis, Mus cervicolor, Niviventer eha, Rattus nitidus, Rattus rattus* and *Suncus murnus.* Out of these six species of rodent and single species of shrew, *Bandicota Bengalensis* and *Rattus rattus* were those species caught only by LMT (Table 10). Because these species cannot inter the tube trap due to small sized and easily escaped from Pitfall trap. LMT was only effective for larger body sized rodent and shrew. Six species trapped by TT were relatively smaller body sized which easily interred into TT. The caught species by TT were *Alticola roylei, Apodemus sylvaticus, Mus cervicolor, Mus musculus, Niviventer eha* and *Suncus murinus*. But TT was effective for capturing smaller body sized rodent and shrew. During overall trapping period, PFT trapped four species of rodent and two species of shrew. *Alticola roylei, Apodemus sylvaticus, Mus cervicolor, Rattus nitidus* were rodent species caught by PFT and *Soriculus macrurus* and *Suncus murinus* were shrew species trapped by PFT. The PFT trapped all body sized rodent and shrew except *Bandicota bengalensis* and *Rattus rattus* with larger body sized.

At altitude 1,200 m, LMT trapped more individuals because species composition was made of larger body sized species (Figure 14 and Table 8). At altitude 1,500 m, both LMT and TT trapped same number of individuals and species but only one species was trapped by PFT. Overall trap success rates of all trap types were relatively low at altitude 1,500 m (Figure 14). It might be due to very low abundance and richness of rodent community as a result of homogenous forest type and understory without much more vegetation for food, shelter and escaping from enemies. At altitude 1,800 m, both LMT and TT trapped almost same number of individuals with individual trap success rate. But PFT trapped very few number of individual (3) with trap success rate of only 3.33%. At altitude 2,100 m, TT over captured the rodent than that of LMT and PFT because there was more abundance of *Apodemus sylvaticus* that was mostly captured by TT than other with success rate of 11.67%. Similarly, at altitude 2,400 m more individuals were captured by TT than other two traps. At this altitude all trapped species of rodent was comparatively smaller in their body sized. Hence it captured more than other.

6. CONCLUSION AND RECOMMENDATIONS

The study of diversity and distribution pattern of small mammals along altitudinal gradient in the mountain of Shivapuri-1, Nuwakot, Nepal recorded 10 species of rodent and shrew with diversity index of 2.06 and trap success rate of 11.55%. The weak negative correlation between species diversity and altitude showed slightly decreasing trend in species diversity of rodent and shrew with increasing altitude but the association was not statistically significant. The variations on distribution and diversity of small mammals along altitudinal gradients were due to variations on dominant forest types and microhabitat availability along altitudinal gradients. The observed deviation of distribution pattern from the generalized pattern of mid-elevational peak and linearly decreasing with increasing altitude might be due to random distribution of suitable microhabitats, influence of human habitation and cultivated land area.

The results of this study revealed that species richness and abundance were positively related with dominant vegetation types and habitat heterogeneity and complexity. The availability and complexity of microhabitats varied with altitude and dominant forest types. The lowest and middle altitudes with higher habitat heterogeneity supported comparatively more number of individuals and species of small mammals than those altitudes with less habitat complexity such as 1,200 m and 1,800 m. Presence of Cultivated land and human habitat area also positively accounted for abundance and diversity of small mammals by providing more food resources and shelter.

The trap used in this study performed sampling of small mammals with great variation of trap success rates and species specificity along altitudinal gradients. The results demonstrated that for trapping wide range of body sized species, pitfall trap was more effective. For larger and smaller body sized species Local mesh trap and Tube trap respectively are preferred. But combination of many trap types are considered to be more complete sampling method due to their supplementary role for sampling all individual species of small mammal community.

On the basis of results and conclusion of this study the following are recommended:

- Since some small mammals are mostly arboreal, only ground trapping of small mammals does not sample small mammalian species completely, hence both ground and arboreal trapping are recommended.
- Long term sampling at all possible microhabitats along multiple transects are recommended for revealing seasonal effect on population abundance and general distribution patterns along altitudinal gradients.
- Due to complementary roles, the application of multiple trapping methods is recommended for complete inventory of small mammal diversity of particular landscapes.

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ANNEXES

Annex 1: Data sheet for daily recording of trapped specimens and temperature.

Altitude: ………………. Date: ……………….

Day	Trap	No. of Individual	Rodent/Shrew	Repetition	Species	Temp. Min	Temp. Max
1	LMT						
	TT						
	PFT						
2	LMT						
	TT						
	PFT						
3	LMT						
	TT						
	PFT						
4	LMT						
	TT						
	PFT						
5	LMT						
	TT						
	PFT						
6	LMT						
	TT						
	PFT						

Annex 2: Data sheet for morphometric measurement of trapped specimens.

Altitude: ………….. Date: ……………..

Day	R/S	Morphometric Measurements						Sex	Species
		Weight (gm)	HB Length (cm)	Tail Length (cm)	FF Length (cm)	HF Length (cm)	Ear Length (cm)		

Annex 3: Data sheet for determining Dominant vegetation

Altitude…………… Vegetation Type……………. Quadrate Size……….

S.N.	Species	Abundance of species in Quadrates			
		Q_1	Q_2	Q_3	Q_4

PHOTOGRAPHS

Mus musculus

Apodemus sylvaticus

Alticola roylei

Niviventer eha

Mus cervicolor

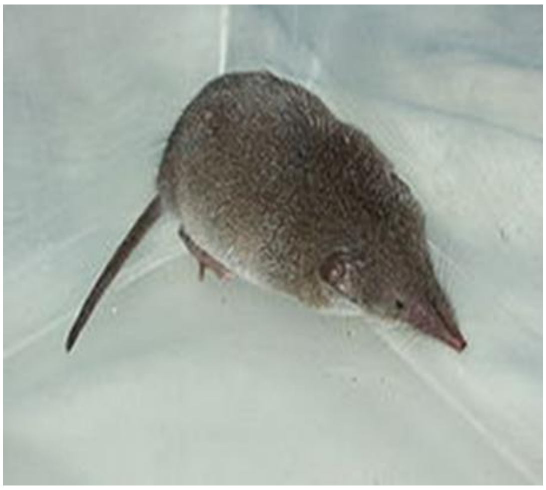
Rattus nitidus

Photo: 2 Trapped murid rodent species.

Rattus rattus

Bandicota bengalensis

Suncus murinus



Soruculus macrurus

Photo: 3 Trapped murid rodent and soricid shrew species.