DIVERSITY, ABUNDANCE AND DISTRIBUTION OF SMALL MAMMALS IN FOREST PATCHES OF KATHMANDU VALLEY, NEPAL

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of Master of Science in Zoology with special paper
Ecology and Environment

Submitted to
Central Department of Zoology
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Tribhuvan University
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August, 2020

DECLARATION

I hereby declare that the work presented in this thesis entitled **"DIVERSITY, ABUNDANCE AND DISTRIBUTION OF SMALL MAMMALS IN FOREST PATCHES OF KATHMANDU VALLEY, NEPAL"** has been done by myself, and has not been submitted elsewhere for the award of any other degree. All sources of information have been specifically acknowledged by references to the author(s) or institution(s).

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RECOMMENDATIONS

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LETTER OF APPROVAL

On the recommendation of the supervisor Asst. Professor Dr. Bishnu Prasad Bhattarai, this thesis submitted by Ms. Sital Budhathoki entitled **"DIVERSITY, ABUNDANCE AND DISTRIBUTION OF SMALL MAMMALS IN FOREST PATCHES OF KATHMANDU VALLEY, NEPAL"** is approved for the examination and submitted to Tribhuvan University, in partial fulfillment of the requirements for the Degree of Master of Science in Zoology (Ecology and Environment).

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CERTIFICATE OF ACCEPTANCE

This thesis submitted by Ms. Sital Budhathoki entitled **"DIVERSITY, ABUNDANCE AND DISTRIBUTION OF SMALL MAMMALS IN FOREST PATCHES OF KATHMANDU VALLEY, NEPAL"** has been approved as a partial fulfillment of the requirements for the Degree of Master of Science in Zoology (Ecology and Environment)

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ABBREVIATIONS AND ACRONYMS

Abbreviated form	Details of abbreviations
m	Meter
asl	Above sea level
kg	Kilogram
ha	Hectare area
km^2	Square kilometer
spp.	Species
GIS	Geographic Information System
IUCN	International Union for Conservation of Nature
SMCRF	Small Mammals Conservation and Research Foundation
SMSG	Small Mammals Specialist Group

ABSTRACT

In Nepal, researches on small mammals are mainly conducted in unaltered habitats such as national parks, high altitudinal forests and grasslands, located far from human settlements. However, forest patches in urban environments also have potentiality for supporting small mammals, providing them with shelter, resources and space for breeding. This study was aimed at exploring diversity, abundance and distribution of small mammals in forest patches of Kathmandu valley. Three sites were selected for the study namely Ranibari community forest, Swayambhunath hillock and Coronation garden. Methods employed were Direct Observation, Roost Survey and Line Transect. Field survey was conducted in June-July, 2019. In selected sites, 250 m transect was established and 25 live traps (Local, Sherman and Tube) were set for capturing species. Trapped individuals were measured, marked and released at the site. Data were analyzed by using MICROSOFT EXCEL 2010, PAST and CANOCO. From a survey of 625 trap nights, 61 individuals representing six species, three orders and four families were identified. Abundance was higher from Ranibari Community Forest having rich floristic constituent. Asian house shrew (*Suncus murinus*) was the most dominant species. Shannon Weiner diversity index revealed moderate diversity (1.26). Diversity pattern was clumped in study areas owing to uneven distribution of resources in natural environment. Species response to five environmental parameters showed significant relation in Ranibari community forest ($F=2.446$, $P=0.018$) and Coronation garden ($F=2.75$ $P=0.05$), whereas it was insignificant in Swayambhunath hillock ($F=1.60$ $P=0.17$). These results suggested that small mammals in urban forest patches were influenced by ground cover, distribution of resources and environmental parameters. Therefore, research on small mammals is suggested to be conducted in other forest fragments in Kathmandu Valley.

1. INTRODUCTION

1.1 Background

Small mammals are defined as small-bodied animals weighing less than one kilogram (SMSG 2011). Generally, this group includes members of three orders such as Rodent, Insectivore and Eulipotyphla. A few ungulates such as Water chevrotian (*Hyemoschus aquaticus*) and Mouse deer (*Tragulus* spp.) smaller than some of the larger rodents and many Mustelids (e.g. ferrets, weasels) which are miniature in size are also categorized as small mammals (Barnett & Dutton 1995). Conversely, mammals that are less than five kilograms are also categorized as small mammals concerning mammals other than rodents, including carnivorous species such as foxes, primates and marsupials (Merrit 2010). These species are terrestrial and world-widely distributed ranging from sea level to the high Himalayan pastures at an altitude of 5000 m (Adhikari 2001). Most of these species are nocturnal and spend much time inside burrows or hidden areas with dense coverage of foliage or detritus. Small mammals, particularly rodents are characterized by a single pair of continuously growing, gnawing incisors in their upper and lower jaws, which enable them to feed successfully on a huge range of different food types. There are over 30 other living rodent families, containing species with a wide range of different ecologies and habits rodents are truly diverse. Similarly, small carnivore like mongoose is vaguely cat-like and mostly feeds on insects, crabs, earthworm, rodents, snakes and other creatures.

Small mammals like the Himalayan marmot found in the Himalayan alpine mountain ecosystem play a vital role as an ecosystem engineer through soil modification resulting from extensive borrowing (Nikol'skii & Ulak 2006). These species have crucial roles in ecosystem as they help in nutrient cycling, habitat modification, consume plants, disperse seeds and create link between primary producers and secondary consumers. Therefore, variation in their diversity, abundance and distribution can alter dynamics of other species too (Ray 1988, Solari et al. 2002).

1.2 Diversity, abundance and distribution

Small mammals constitute more than 2800 species, out of which 437 are considered to be threatened with extinction by the International Union for the Conservation of Nature. Volant and non-volant small mammals constitute almost 73% of the world's mammalian diversity with just the non-volant small mammals contributing a little over 52.5% (Amori

& Gippoliti 2000). In South Asia, a total of 185 non-volant small mammal species are known out of which 62 are endemic to the region and 123 are non-endemic species (Molur et al. 2005). In Nepal, a total of 208 mammal species recorded among which 79 are small mammals (Baral & Shah 2008). In addition to this, 53 species of bats have also been identified (Acharya et al. 2010). However, due to lack of research it is still among the least concern taxon and is very poorly studied.

Information regarding diversity, abundance and distribution plays a vital role for enhancing our knowledge about biology of species as well as for analyzing their state in habitat and for assessment of conservation and decision making for conservation (Wang et al. 2007). Small mammals are widely distributed creatures and are susceptible to disturbances. Hence, these species are often used as an indicator by experts to assess landscape conditions (Clark et al. 1989). Land topography, altitude, vegetation and ground cover from sea level, lowland to high Himalayan pastures are some of the factors that affect the distribution and abundance of small mammals (Adhikari 2001). The study of abundance and distribution of animals in relation to different ecological components that govern them such as habitat features and anthropogenic disturbances help to know about the relative significance of these components in driving animal occupancy patterns and abundance (Burnham et al.1980).

Among other small mammals, rodents form a vital component of free state ecosystem. Their community structure and species richness have been related to habitat structure and complexity, area, productivity, predation, trampling and grazing, surrounding landscape and the distance between similar habitats, maturity of the habitat succession of the vegetation, and the presence of exotics (Avenant 2000). In general, changes in rodent habitats are associated with changes in rodent diversity and community structure. Ecological disturbance of these habitats is associated with the presence or absence of indicator species and decreases in rodent species richness. However, the mechanisms of these relationships are extremely complex.

1.3 In context of urban environment

In urban areas, there is higher degree of fragmentation in natural as well as semi-natural habitats. There is comparatively lesser connectivity between forest patches too owing to construction of roads and infrastructures. Due to these reasons, the existing forest patches resemble islands, which results in alteration in plant and animal communities. The

mammals living in such condition are compelled to roam around man-made modification such as road surfaces, which lie at a closer distance to forest margins (Oley et al. 1974).

Eventually, these factors affect small mammal population (Baker et al. 2003). Unfavorable management practices, for instance, application of chemicals, periodic removal of shelter, vegetation and greater predation pressure from domestic cats also affect small mammals in an urban setting (Baker et al. 2000). On the flip side, closer proximity to residential areas may demonstrate an appropriate habitat for small mammals as they offer food opportunities and microhabitat. Practices of householders like plantation of fruit and seed bearing plants, use of compost manures and less dependence on chemical fertilizers can also benefit wildlife in city areas (Good 2000).

Thus, in order to manifest an urban environment, small mammals should be able to disperse in such remnant patches and persist in these patches long enough to breed and produce offspring. Dispersal is primarily aided by corridors of vegetation, whereas hampered by roads and buildings (Yalden 1980).

1.4 Objectives

1.4.1 General objective

To explore diversity, abundance and distribution of small mammals in three forest patches of Kathmandu Valley namely Ranibari community forest, Swayambhunath hillock and Coronation garden, Kirtipur.

1.4.2 Specific objectives

- To investigate diversity and abundance of small mammals in the study sites.
- To evaluate the distribution pattern of small mammals.
- To determine the impact of environmental parameters on abundance of small mammals.

1.5 Research question

Do environmental parameters affect abundance of small mammals?

1.6 Rationale of the study

Small mammals are one of the least known mammalian group with 43% being categorized as Least Concerned, 48.1% are Data Deficient and only 8% are considered

Endangered (Jnawali et al. 2011). Articles and regarding small mammals are not abundant as researches are mainly focused on flagship species such as Greater one-horned rhinoceros (*Rhinoceros unicornis*), Bengal tiger (*Panthera tigris tigris*), etc. Studies are even rarer in context of forests in urban areas such as Kathmandu, capital city of Nepal. There are some studies that aimed on vegetation of these forest patches. However, information regarding small mammals is inadequate for Kathmandu area. Thus, a baseline data of small mammals specifically focusing on their diversity and distribution in such human influenced region is a mandatory requirement to develop an efficacious conservation plan of these faunal species.

2. LITERATURE REVIEW

2.1 Diversity and abundance of small mammals

Study carried out by (Bhattarai 2012) on non-volant small mammals in Parsa Wildlife Reserve recorded six species such as Asian house shrew (*Suncus murinus*), Small asian mongoose (*Herpestes javanicus*), Small indian civet (*Viverricula indica*), Lesser bandicoot rat (*Bandicota bengalensis*), Common palm civet (*Paradoxurus hermaphroditus*) and Porcupine in a total of 252 trap nights. Two study sites were selected where live trap placement as well as vegetation survey were conducted simultaneously. SMCRF (2015) conducted a biodiversity survey of Chandragiri hill, Kathmandu, Nepal and recorded 13 species of mammals including House rat (*Rattus rattus*), Orange-bellied himalayan squirrel (*Dremomys lokriah*), Yellow-throated marten (*Martes flavigula*), Small asian mongoose, Himalayan goral (*Naemorhedus goral*), Barking deer (*Muntiacus muntjak*), Wild boar (*Sus scrota*), Rhesus monkey (*Macaca mulatta*), unidentified bats and rodents, 137 species of birds, 53 species of butterfly and 9 species of herpetofauna.

Seventeen species of mammals were recorded by (Lamsal et al. 2014) in Ghodaghodi lake complex. Among the recorded species, nine were identified as small mammals such as Squirrel, Flying squirrel, Fishing cat (*Prionailurus viverrinus*), Leopard cat (*Prionailurus bengalensis*), Jungle cat (*Felis chaus*), Indian hare (*Lepus negricollis*), Otter and Bat species, in both Volant and non-volant categories, where Direct Observation, Focus Group Discussion (FGD) and Interview with Key Informants (KII) were the adopted methods. He also attempted to identify potential threats to biodiversity in the study site. Consequently, over cultivation, over grazing, poaching, forest fragmentation, habitat destruction, water pollution, excessive use of chemical fertilizers and haphazard irrigation channels were contributing factors to the growing issue. Kunwar (2017) investigated abundance and distribution of small mammals excluding volant species in Ghodaghodi lake complex, Kailali, where the site was categorized into 4 habitats such as croplands, grassland, mixed forest and riverine forest. Altogether, 72 individuals belonging to 10 different species with four orders and eight families were recorded by using methods of live trapping, camera trapping and roost survey along with direct observation. Asian house shrew was identified as dominant species and House rat was second abundant species.

Chalise (2013) carried out a research about the presence and absence of Red panda (*Ailurus fulgens*) around Polangpati area of Langtang National Park and noted some indirect signs. Pandey & Kaspal (2011) carried out a research in Koshi Tappu Wildlife Reserve with an aim to identify small mammals. Four sampling blocks were established as per sign abundance. Consequently, five species belonging to four orders and four families were documented.

2.2 Distribution of small mammals

Distribution and diversity of small mammals were studied by (Dahal et al. 2011) for a month in Chitwan National Park. His study recorded 12 species of small mammals from three habitat types: Forest, Grassland and Riverine habitats. Small civet cat was most frequently captured species, whereas only one species of Scuridae family contributed to species richness. Nembang (2003) carried out a survey to determine status and distribution of small mammals in relation to habitat features in Shuklaphanta Wildlife Reserve. Within 512 trap nights, 76 individuals representing 12 different species were captured. Eight species belonged to order Rodentia followed by order Insectivora with two species and remaining two belonged to order Carnivora and order Lagomorpha respectively.

Similarly, Adhikari (2014) investigated abundance and distribution of non-volant small mammals in Riverine and Sal forests using three trapping methods (Elliot, Pitfall and Camera). As a result, abundance was greater in former site in comparison to the latter one, while distribution pattern was clumped in the very site. Also, 14 species were captured and identified in trapping effort of 1080 trap nights. Asian house shrew was identified as dominant species and House rat was second abundant species. Survey on terrestrial small mammals commenced by (Molur & Singh 2009) led to a finding that among 412 trapped individuals, 14 species were recorded. The most common species was Black rat (*Rattus wroughtoni),* whereas Asian house shrew was found to be widely distributed in Nepal, India, Pakisthan, Bhutan, Bangladesh and Srilanka (Molur et al. 2005). Shrestha & Basnet (2005) identified Indian leopard (*Panthera pardus fusca*), Jungle cat, Large indian civet (*Viverra zibetha*), Golden jackal (*Canis aureus*), Himalayan black bear (*Ursus thibetanus laniger*), Yellow-throated marten, Small asian mongoose, Himalayan goral, Barking deer, Wild boar, Rhesus monkey, Hanuman langur (*Semnopithecus*), Chinese pangolin (*Manis pantadactyla*), Indian crested porcupine (*Hystrix indica*), Himalayan pika (*Ochotona himalayana*), Black-naped hare (*Lepus*

nigricolis), Orange-bellied himalayan squirrel, Fawn-coloured mouse (*Mus musculus*), Brown-toothed shrew (*Crocidura nigricans*) and Black rat in a field study carried out from July 2003 to July 2004.

2.3 Impact of environmental parameters on small mammals

Gomes et al. (2011) had conducted a research which tested response of small mammal communities in fifteen patches remnant natural and semi-natural habitat in Porto Metropolitan Area (Portugal) and concluded that both species diversity and abundance were negatively affected by urbanization. The study also clarified that understanding response small mammals could be beneficial for identifying position of fauna in ecosystem as well as for management practices. Due to flourishing human civilization, destruction and fragmentation of natural habitats is a common issue, which leads to alteration in plant and animal communities. Reduction of structural diversity, loss of natural habitat and increase isolation of habitats are major consequences of extensive fragmentation. Construction of road and traffic creates barrier effect for most species, including small mammals as it break microclimatic conditions at edge of road, increases disturbances such as noise, dust and toxic fumes and invites risk of being killed on road (Mader 1984). Christain (1980) studied response of small mammals to availability of water resource in Namib desert rodents and suggested that availability of water resource makes microhabitat conditions suitable and reduces the use of dense cover and increased their use of open patches.

3. MATERIALS AND METHODS

3.1 Study area

Kathmandu valley occupies an area of 642 km^2 and lies at an altitude of 1339 m above sea level. It is located within 85°22'E and 27°42'N far from the huge water bodies and surrounded by high hills and rugged topography of varying altitudes. Bagmati and Bishnumati are the major rivers of the valley. The valley has sub-tropical climate with high humidity, rainfall and precipitation in summer. Mean maximum temperature ranges between 20°C in December and 29°C in April, while the mean minimum temperature varies between 2°C in January and 20.1°C in July. In January, the temperature falls to the lowest (-1°C), and in April it rises to the maximum (32°C).Rainfall is mainly by summer monsoon. Average annual rainfall of Kathmandu valley is about 1600 mm.

The selected three forest patches inside Kathmandu valley are Ranibari community forest, Swayambhunath hillock and Coronation garden, Kirtipur.

3.1.1 Ranibari community forest

Ranibari forest, situated in north-western region of Kathmandu valley, occupies an area of 6.95 ha and is located at an altitude of 1,303 m asl. Though the site is a natural forest, it is modified at times due to human interference and plantation management.

A total of 108 vascular species including 54 trees belonging to 58 families and 92 genera were recorded (Maharjan 2003). Ranibari represents a mixed forest type which constitutes both regional species as well as exotic ones. Some regional flora includes Himalayan maple (*Acer oblongum*), Chilaune (*Schima wallichi*) and Bolly gums (*Neolitsea cuipala*), whereas Bunya pine (*Araucaria bidwillii),* Jacranda (*Jacaranda mimosifolia)* and Poplar gum (*Eucalyptus alba*) are examples of introduced species. Similarly, numerous plant species such as Bamboo (*Dendrocala mushamiltonii*), Kavro (*Ficus lacor*), Jujube bush (*Zizyphusin curva*), etc. are also well-flourished in this forest, while bamboo patches are also dominant species.

Since this area lies in closer proximity to human society and has a narrow coverage, species richness is not abundant. Animals such as Small asian mongoose, Irrawaddy squirrel, Golden jackal, Rhesus monkey as well as wild cats are also found to be residing here.

3.1.2 Swayambhunath hillock

Swayambhunath lies in 27°42'N and 85°17'E and the hillock ranges from 1350-1405 m asl. Located in western region of Kathmandu valley, this hillock is also believed to be extention of Nagarjun forest however at present, it is heavily invaded by human encroachment. Spread in an area of 35 ha, this region supports the life of many floral and faunal species.

This region is represented by both naturalized as well as exotic plant species. The southern slope mainly harbours natural as well as exotic species, whereas north and north-western has aided some native plant species. Altogether, this region has 104 species with higher contribution of Angiosperm at 98 species and lesser evidences of Gymnosperm species (Ranjitkar & Chaulagain 2004). A list of 52 families of Angiosperm belonging to 87 genera has been recorded, while three families of Gymnosperm species indicating presence of five genera are mentioned. Some common vegetation of this area comprises Chilaune, Chir Pine (*Pinus roxburgii*), Parsi (*Pyrus pashia),* Juniper (*Juniperus* spp.), Monkey puzzle tree (*Araucaria imbricate*), etc. Similarly, ground layers have a dominant composition of Sticky snakeroot (*Eupatorium adenophorum*), Banmara (*Lantana camara*), Ashuro (*Justicia adhatoda*), Cannabis (*Cannabis sativa*), Taro (*Colocasia* spp.), etc. Rhesus monkey is a prominent species that is commonly found dwelling in and around Swayambhunath hillock. Small asian mongoose and other small mammals are also found in this area.

3.1.3 Coronation garden

This study site lies in southwest from centre of Kathmandu covering an area of 276 ha. It is located between 85°16'E and 27°40'N and is situated at 1280-1400 m asl.

As this area is a planted site, vegetation is characterized by the presence of Chilaune, Utis (*Alnus nepalensis*), Chinkapin (*Castonopsis indica*), Khasru (*Quercus lanata*) and Cotoneaster (*Cotoneaster bacillaris*) as well as other exotic species such as Kapur (*Cinnamonum camphora),* Crimson Bottlebrush (*Callistemon Lanceolatus*), Juniper, etc. Small asian mongoose and other small mammals are also found in this area.

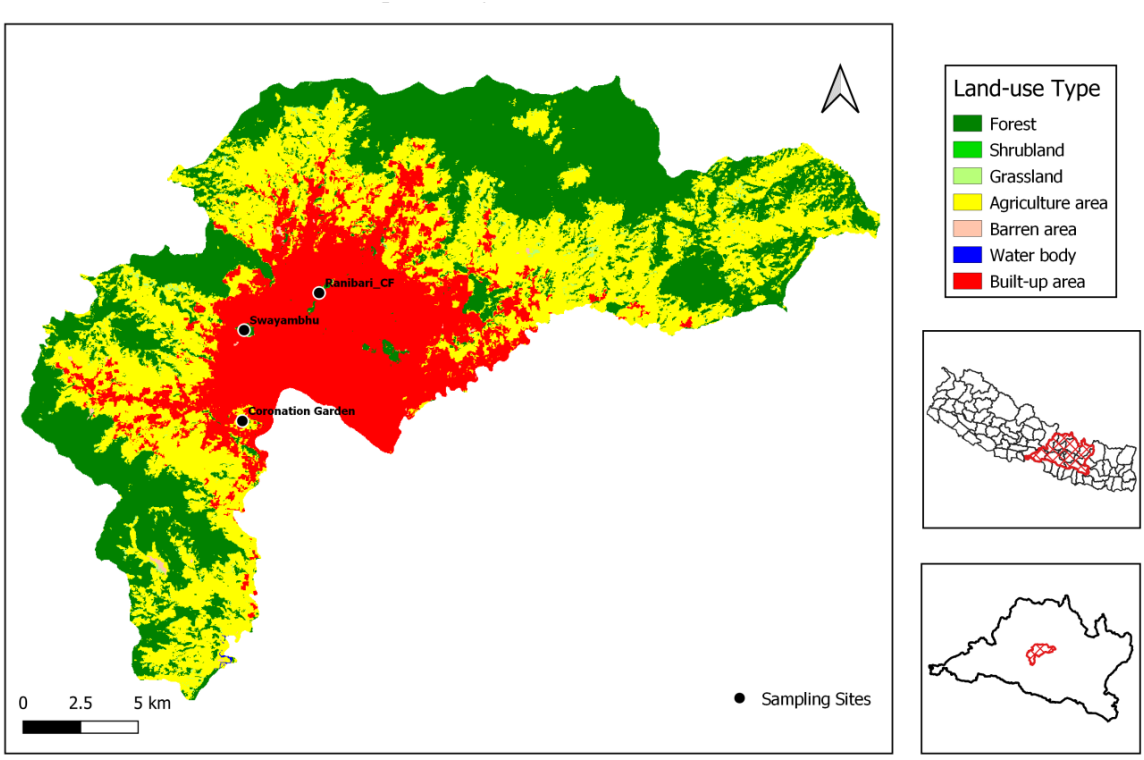

Figure 1: Map of study area

3.2 Materials

Following tools were used for data collection:

- Live traps (Local traps, Sherman traps and Tube traps)
- Camera (Nikon D3200)
- Binocular (Kylietech 12×42)
- Densiometer
- Measuring tape and Measuring scale
- Weighing machine and Capture bag
- Stationaries

3.3 Research design

This study was conducted in three plots of the selected study sites. A 250 m long transect was selected for the carrying out the sample survey. Twelve sets of traps were placed

parallel to each other having a difference of 10 m from the midline. The width of plot was up to 20 m wide on either side of the midline, such that each trap was set 10/10 m left and right from the midline. The 13th trap was set on the midline at the 250 m to mark the end of the transect (Figure 2).

3.4 Small mammals sampling

The quantitative data on small mammals were collected by using live traps such as Local Traps, Sherman Traps and Tube Traps set along the transect. Field survey was conducted from June 15 to July 13, 2019. During this period, an interval of one to two days were allocated in order to clean and maintain trapping equipments to prevent bad odour and dirt before shifting to next study site. A trapping period of three to four consecutive nights per plot was allocated. Two series of animal sampling were conducted such as capturing followed by recapturing. Altogether 625 trap nights was considered during this study. Trap nights refer to the number of traps used per plot multiplied by total nights employed.

3.4.1 Bait

Bait consisted of oatmeal flavoured with peanut butter, which is a popular bait choice among many mammalogists. Along with that, fried fish, some pieces of potatoes, carrots and bread were sufficiently used in all traps. Traps were set before sunset and it was checked and re-baited each morning. As each trap was placed, leaf litters were used along in order to form a firm base as well as to cover the visible parts of traps except the entrance opening. Red colour ribbons were tied on twigs of shrubs and branches of tree nearby trapping stations to locate each trap.

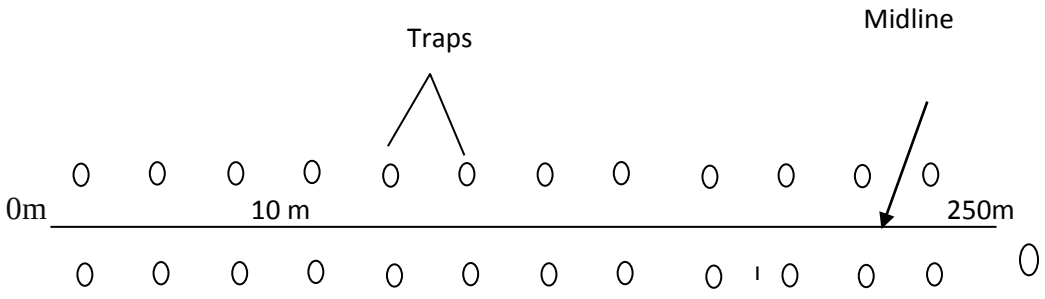

Figure 2: Positioning of Traps in 250 m transect (Hero et al. 2011, Adhikari 2014).

3.4.2 Direct observation

During field survey, small mammals that were observed while setting traps, walking on transects and checking of traps were noted on a notebook.

3.4.3 Roost survey

Binocular was used to scan bark of trees during daytime. This method was adopted to locate arboreal small mammals such as squirrels.

3.5 Animal handling and study on captured animal

During animal handling, protective gloves were worn as a general precaution. Great amount of caution was taken in order to avoid stress and injury to the animal. At first, the trapped animal was transferred to a clear, strong plastic bag. Both animal and bag were weighed together, after which the weight of bag was subtracted to get an accurate measure of the animal's body weight. Bags were reweighed quite often due to presence of moisture and detritus, which added extra weight to the bag. For taking other measurements, the animal was taken out from bag by firmly grasping the nape of neck that restricted the head movement. The ventral surface of animal's body was exposed and necessary measurements were taken.

Morphometric data on small mammals were recorded that included head and body length, tail length, ear length, sex determination and reproductive condition in female (pregnant or lactating). Measurements were taken by a measuring scale. Sexing criteria (except shrew species) was based on the distance between anus and the vagina. The distance between anus and vagina is shorter in female than the distance between anus and penis in males. Abundant photographs of species were clicked in order to ease the identification procedure. Then, each captured animal was individually marked by fur clipping with the help of scissors and released immediately at the same place from where they were captured (Gurnell & Flowerdew 1990). It is a convenient method for short term experiments since the mark is visible for few days and recounting the same individual is also prevented. Additionally, it does not have detrimental impacts on animals. All the captured animals were identified up to species level based on the morphological characters using standard literatures (Prater 1971, Menon 2009 and Jnawali et al. 2011).

3.6 Measurement of environmental parameters

Microhabitat measurements were obtained where each live-trap was placed. Five environmental parameters such as Distance to settlement (DTS), Distance to road (DTR), Distance to water (DTW), Open canopy cover and Closed canopy cover. First three parameters were obtained manually with tape measure and divided into scales, which were equivalents to: 1(0-50 m); 2(51-100 m) and 3(>100 m). Similarly, canopy cover was estimated by using a spherical densitometer (Lemmon 1956). The equipment comprises of a concave or convex mirror with a total of 24 frames, where each frame is divided into four parts. Each part has the value of one. Based on is reflection of canopy image on each frame, canopy cover percentage is calculated. An index of 1.04 is used for accuracy. Presence up to 30% of canopy cover at trapping station was classified as Open canopy cover, whereas canopy that exceeded 30% was classified as Closed canopy cover.

3.7 Data analysis

3.7.1 Diversity, abundance and distribution of small mammals

Diversity of species was measured as the total number of species recorded in the plot. The study of distribution and abundance of organism is recognized as an important issue in ecology (Burnham et al. 1980). The study of abundance and distribution of animals in relation to ecological factors like habitat features and anthropogenic disturbances helps in understanding the relative importance of these factors in determining occupancy patterns of animals.

Species abundance was analyzed by dividing total number of each species per number of plot in which it occurred (Krebs 1985). Similarly, distribution pattern of small mammals was analyzed by calculating the variance-mean ratio ($S^2 / \overline{X}$) as,

If $S^2 / \overline{X} < 1$, Distribution is uniform

If $S^2 / \overline{X} = 1$, Distribution is random

If $S^2 / \overline{X} > 1$, Distribution is clumped

Where, S^2= variance = $1/n \sum (X-\overline{X})^2$

Where, $\overline{X}$ = mean value

These data were analyzed using Microsoft Excel 2010.

3.7.2 Species diversity index

The diversity of species was measured by using Shannon Weiner diversity index.

Shannon Weiner diversity index is designated as H, which is calculated as:

$$H = -\sum (n_i/N) \log_e (n_i/N)$$

Or, if $P_i = n_i/N$

$$H = -\sum P_i \log_e P_i$$

Where,

Σ represents sum of Pi (lnPi)

H'= Index of species diversity

Pi = the proportion of individuals in the i^{th} species, $Pi = n_j/N$

n_i =Importance values for each species

N =Total Importance value.

3.7.3 Species-environmental parameters relation

Species response to different environmental parameters and habitat were analyzed by using Canonical CANOCO version 4.56 (TerBraak & Šmilauer 2002). The significance of the predictors was tested using Monte Carlo permutation test.

4. RESULTS

4.1 Diversity and abundance of small mammals

Overall, 61 individuals belonging to six species of small mammals were identified by using live traps, direct observation and roost survey. In the first capture series, 34 individuals were trapped, whereas 27 individuals were trapped in second capture series. These species represented three orders and four families. Out of which, four species were members of order Rodentia and remaining two belonged to order Euliphotopyla and order Carnivora respectively. The recorded and identified species were Asian house shrew, House rat, Bandicoot rat, Eastern house rat (*Mus musculus*), Irrawaddy squirrel (*Callosciurus pygerythrus*) and Small asian mongoose (Table 1). Former four species were captured with the help of live traps, while latter two species were encountered through direct observation in and around transect and bark of trees respectively.

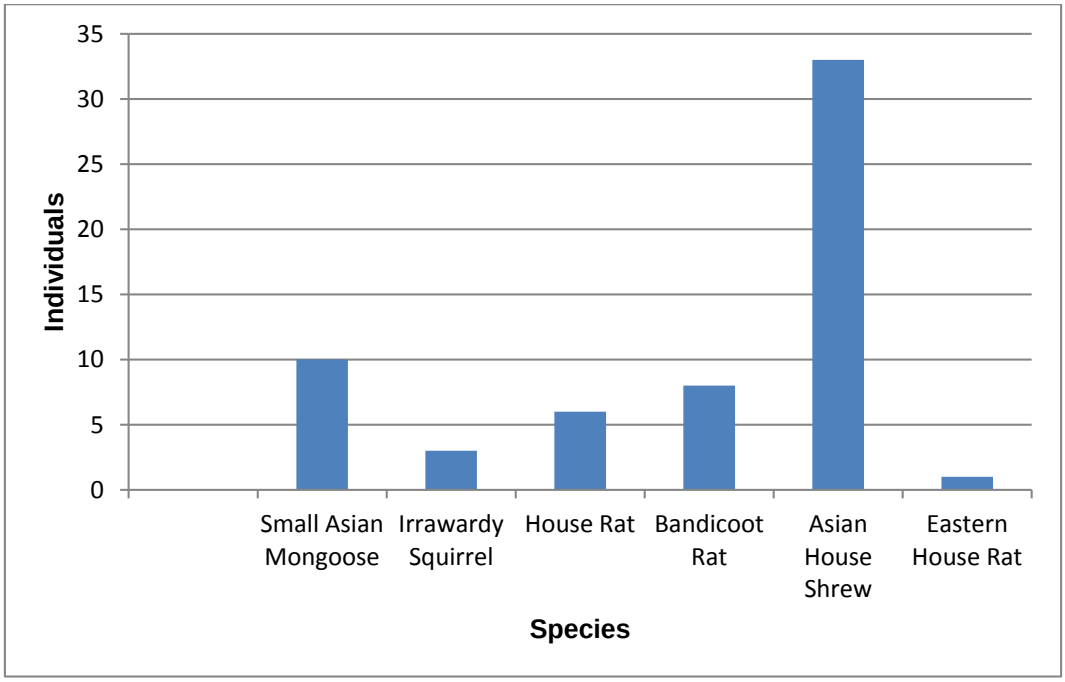

Figure 3: Number of species of small mammals

A total number of five species including Asian house shrew, House rat, Bandicoot rat, Small asian mongoose and Irrawaddy squirrel occurred in Ranibari community forest. Among these species, Irrawaddy squirrel was observed only in Ranibari community forest through direct observation and roost survey.

Similarly, four species were noted from Swayambhunath hillock such as Asian house shrew, House rat, Bandicoot rat and Small asian mongoose. First three species were captured in live traps, whereas remaining one was encountered on regular field visits.

Five species were identified during field survey in Coronation garden. However, Eastern house rat was captured only from Coronation garden.

Table 1: Small mammals with their respective orders and families

SN	Order	Family	Scientific name	Common name	Local name
1	Carnivora	Herpestidae	*Herpestus javanicus*	Small asian mongoose	Nyauri muso
2	Rodentia	Muridae	*Rattus rattus*	House rat	Ghar muso
			Mus musculus	Eastern house rat	Duhure muso
		Sciuridae	*Bandicota bengalensis*	Lesser bandiccot rat	Khet muso
			Callosciurus pygerythrus	Irrawaddy squirrel	Lokharke
3	Eulipotypyla	Soricidae	*Suncus murinus*	Asian house shrew	Chuchundro

Overall, during the field survey conducted from June to July, 61 individuals of small mammals belonging to three orders were recorded in a total of 625 trap nights.

Asian House Shrew had the highest abundance reported at 11 with a count of 33 individuals followed by Small asian mongoose at 3.33 (10 individuals). Eastern house rat, on the other hand, had only a representative, having least abundance at one (Table 2).

Table 2: Abundance of small mammals in Ranibari community forest, Swayambhunath hillock and Coronation garden.

Species	Number of individuals	Plots			No of plot species occurred	Abundance of species
		RB	SW	CG		
Small asian mongoose	10	5	2	3	3	3.33
Irrawaddy squirrel	3	3	0	0	1	3
House rat	6	2	2	2	3	2
Bandicoot rat	8	4	2	2	3	2.67
Asian house shrew	33	11	16	6	3	11
Eastern house rat	1	0	1	0	1	1
	61	25	23	13		23

Shannon Weiner diversity indices for each selected sites in Kathmandu Valley were estimated. Shannon Weiner diversity indices of small mammals in Ranibari community forest was 1.43, that Swayambhunath hillock was 1.42 and for Coronation garden , it was 0.94.

Table 3: Diversity of small mammals in study area

Parameters	RB	CG	SH
Taxa	5	5	4
Individuals	25	13	23
Dominance	0.28	0.28	0.51
Simpson	0.72	0.71	0.48
Shannon	1.43	1.41	0.94
Evenness	0.83	0.82	0.64
Equitability	0.89	0.88	0.68

4.2 Distribution of small mammals

Distribution pattern of small mammals in Ranibari community forest, Swayambhunath hillock and Coronation garden were clumped with variance to mean ratio 3.4, 9.43 and 2.3 respectively. Variance to mean ratio was found to be significantly greater than one indicating an uneven diversity pattern in the study area.

4.3 Species-environmental parameters relation

The assessment of species-environment relation in Ranibari community forest showed that Bandicoot rat had a positive correlation with Open canopy cover and habitat nearby water sources. Similarly, House rat represented closer affinity with settlement, whereas Asian house shrew showed affinity towards Closed canopy cover (Figure 3).

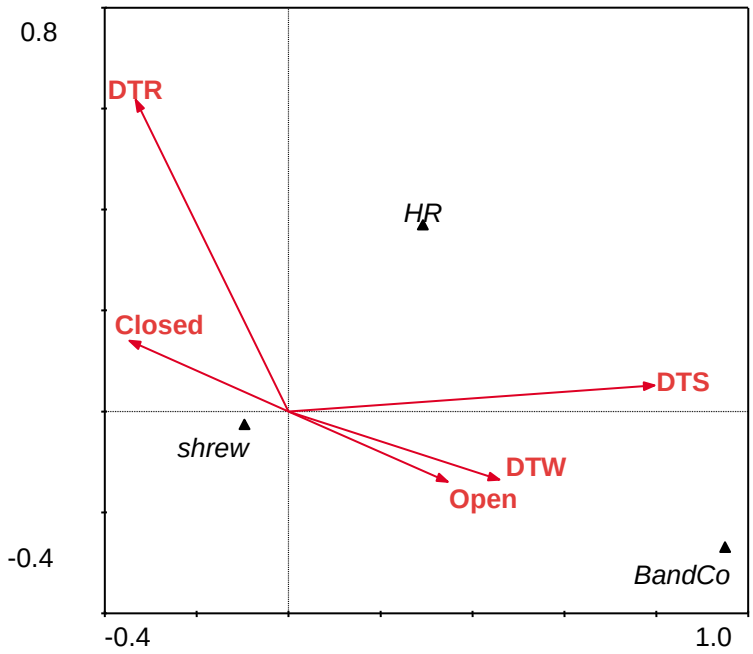

Figure 4: CCA ordination diagram (biplot) showing species (BandCo: Bandicoot rat, HR: House rat, shrew: Asian house shrew) response to different environmental parameters (DTR: Distance to road, DTS: Distance to settlement, DTW: Distance to water, Open: Open canopy cover, Closed: Closed canopy cover) in Ranibari community forest. Monte-Carlo permutation test of significance of all canonical axes. Trace = 0.8, F-ratio = 2.446, P-value = 0.018. First two axes are displayed. The first axis accounts for 77.4% and the second axis 22.6% of the variability.

Analysis of CCA interpreted that Bandicoot rat had a positive correspondence to Open canopy cover. Likewise, Asian house shrew was captured mostly from trapping stations

that were close to settlement and water sources, whereas House rat was trapped from area which were close to road (Figure 4).

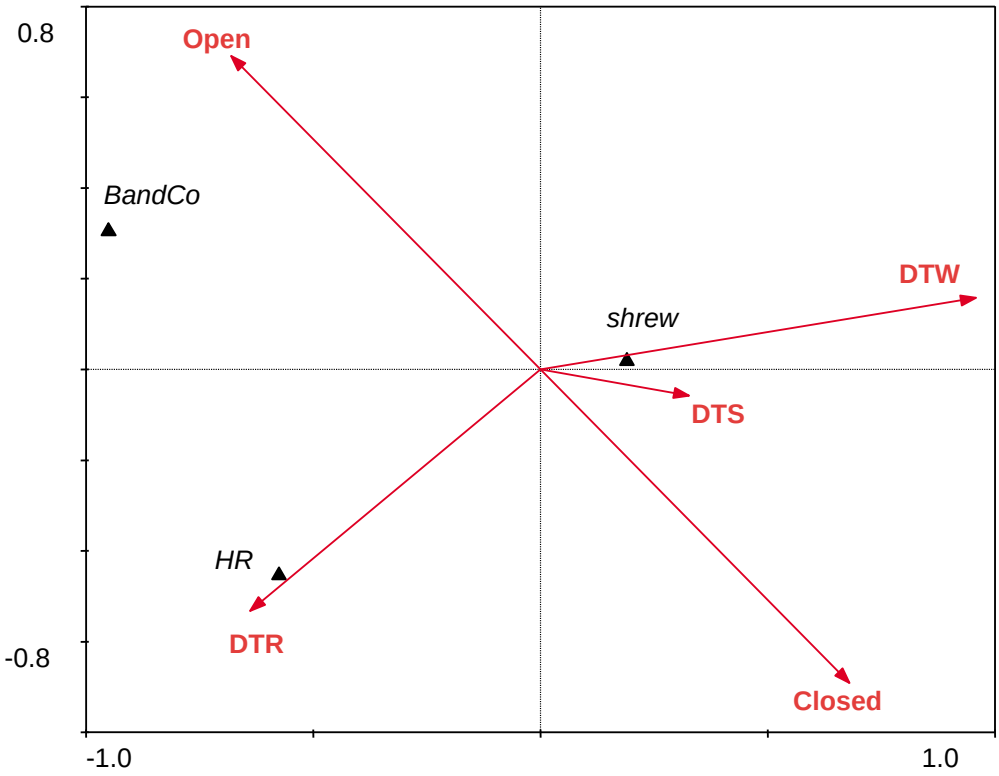

Figure 5: CCA ordination diagram (biplot) showing species (BandCo: Bandicoot rat, HR: House rat, shrew: Asian house shrew) response to different environmental parameters (DTR: Distance to road, DTS: Distance to settlement, DTW: Distance to water, Open: Open canopy cover, Forest: Closed canopy cover) in Swayambhunath hillock. Monte-Carlo permutation test of significance of all canonical axes. Trace = 0.304, F-ratio = 1.604, P-value=0.176. First two axes are displayed. The first axis accounts for 83.5% and the second axis 16.5% of the variability.

The CCA diagram represents that Open canopy cover influenced the capture of Bandicoot rat. Similarly, Asian house shrew and Eastern house rat had positive link with settlement and road. House rat was seen to forage nearby water source and Closed canopy cover (Figure 5).

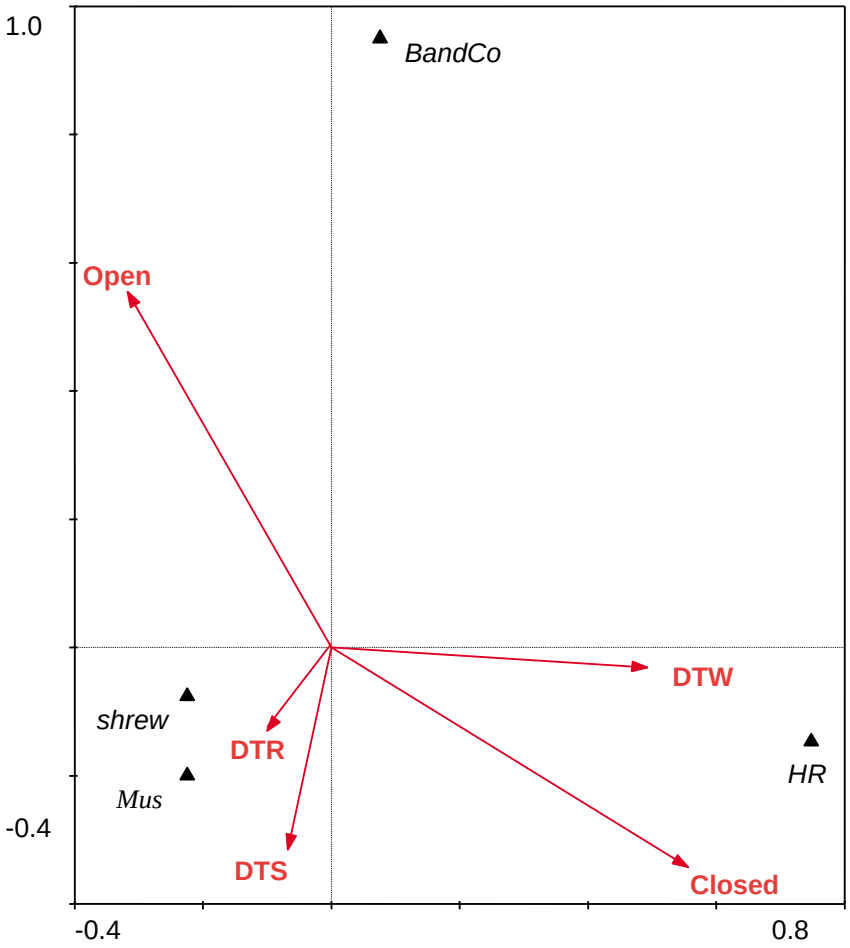

Figure 6: CCA ordination diagram (biplot) showing species (BandCo: Bandicoot rat, HR: House rat, shrew: Asian house shrew, Mus: Eastern house rat) response to different environmental parameters (DTR: Distance to road, DTS: Distance to settlement, DTW: Distance to water, Open: Open canopy cover, Forest: Closed canopy cover) in Coronation Garden. Monte-Carlo permutation test of significance of all canonical axes. Trace = 2.1, F-ratio = 2.755, P-value = 0.05. First two axes are displayed. The first axis accounts for 47.6% and the second axis 32.9% of the variability.

5. DISCUSSION

5.1 Diversity and abundance of small mammals

As it is revealed by results, four species were common in all three forest patches such as Asian house shrew, Small asian mongoose, Bandicoot rat and House rat. Asian house shrew was dominant in all forest patches. Kunwar (2017) investigated abundance and distribution of non-volant small mammals in Ghodaghodi Lake Complex, Kailali and identified Asian house shrew as dominant species. Similar finding was observed by (Bhattarai 2012) as Asian house shrew was identified as the dominant species among six different species of small mammals in Parsa Wildlife Reserve by using Sherman Live traps in grasslands rich with Cynodon grass (*Cynodon dactylon*), Wild sugarcane (*Saccharum spontaneum*), etc. Higher record of Asian house shrew might be due to it's higher reproductive potential, low risk of predation as well as great thriving capacity of this species. Similarly, Irrawaddy squirrel was observed only from Ranibari community forest. The reason might be because of presence of taller trees and dense vegetation that suit such species. Also, Eastern house rat was recorded from Coronation garden only as they are considered to live in closer proximity to human, around houses and croplands. Since there is presence of cropland around Coronation garden, this species might have been captured. However, two remaining study sites do not have any cultivated lands adjacent to them.

Abundance of small mammals was slightly greater in Ranibari community forest than in Swayambhunath hillock and Coronation garden. The reason for higher small mammals in Ranibari community forest might be due to rich floristic constituent as there is presence of bamboo clums and trees like Pipal tree (*Ficus religiosa*), etc. as well as fruiting plants such as White mulberry (*Morus alba*) and Honeyberry (*Caltis australis*), which provides good cover as well as foraging sites. Likewise, in Swayambhunath hillock, small mammals were mostly captured from area rich in vegetation cover such as Chilaune, Asuro, Cannabis, Taro, etc and nearby unused houses though capture was null from the trapping stations with little or no ground cover. Nembang (2003) reported that the abundance of small mammals was high in the area with dense ground vegetation cover and proximity to water source. His study suggested that higher abundance of small mammals is due to the presence of higher vegetation cover. Coronation garden was the site from where least number of animals were trapped. It might be due to grazing of livestocks as well as presence of higher cover of invasive species such as Titepate

(*Artemisia vulgaris*), Banmara as well as thorny plants such as Wild eggplant (*Solanum surattense)*. Because these plants have unpleasant odour and bear inedible seeds and fruits, small mammals tend not to forage area rich in these plant species. Livestock grazing and response of small mammals studied by (Rosenstock 1996, Johnston & Anthony 2008) revealed a finding that small mammals were less abundant in heavily grazed sites in comparison to lightly grazed sites. This suggests that these species depend on herbaceous material for foraging, cover and nests, and when these resources are trambled or consumed by cattle, it affects small mammals negatively (Bailey 1936, Smith 1936, Hall 1946).

5.2 Distribution of small mammals

In this study, distribution pattern of small mammals was noticed to be clumped. Resembling result was observed by (Adhikari 2014, Kunwar 2017). Clumped distribution is usually an outcome of aggregation of individuals in response to various factors like daily or seasonal weather change, habitat differences, reproductive phenomenon or the social attractions (Odum & Barrett 2005). In a natural habitat within the same boundary, some regions might be more appropriate than others due to abundance of resources such as food, water, cover and appropriate microhabitat conditions. Since resources are not proportionately distributed within a single habitat, many individuals tend to congregate in suitable area for survival. This factor leads uneven distribution of species. Presence of rich ground cover and vegetation structure also creates niche types that has a key role in shaping structure of small mammal community as well as diversity in forest ecosystem (Pattern 1997). Furthermore, the distribution and abundance of small mammals greatly varies over time, probably partly in response to climatic variation (Brown & Heske 1990).

5.3 Species-environmental parameters relation

In this study, road which is generally considered to be a restricting factor for mobility of species, has shown positive influence on small mammals such as House rat in Swayambhunath hillock, and Asian house shrew and Eastern house rat in Coronation garden respectively. Similar observation was noted by (Bellamy et al. 2000), where abundance of small mammals were compared with road verge characteristics. However, a contradictory result was documented by (Mader 1984). This suggests that small mammals correspond positively to disturbance such as road only when the surrounding environment is supported by vegetation, which provides a foraging ground as well as shelter for them,

whereas the same parameter acts as a barrier for survival if the adjacent land is not supported by plant species.

Likewise, House rat captured from Ranibari community forest, Asian house shrew from Swayambhunath hillock and Coronation garden had displayed a common pattern where they responded positively with human settlement. Finding similar to this result was drawn by (Good 2000, Nakamoto & Nakanishi 2013). A potential reason for this scenario might be availability of appropriate habitat for small mammals in closer proximity to settlement, which offered them food opportunities and microhabitat. However, unfavorable management practices, for instance, application of chemicals, periodic removal of shelter, vegetation and greater predation pressure from domestic cats also affect small mammals in an urban setting (Baker et al. 2000).

Capture of Bandicoot rat, Asian house shrew and House rat from Ranibari Community forest, Swayambhunath hillock and Coronation garden responded positively with water availability in this research. Christain (1980) had an analogous finding. In the study, it was demonstrated that increased water availability reduced use of dense cover along with preference of open patches by small mammals thus, altering suitability of certain microhabitats. Energy and water requirement of small mammals during pregnancy and lactation also explains the inclination of rodents towards water rich sites (Baverstock & Watts 1975, Smith & McManus 1975).

In this study, reduced canopy cover in the vicinity of trapping station was associated with greater frequency of Bandicoot rat. A homogenous finding was reported by (Deuser & Shugart 1978, Puttker et al. 2008, Yahner 2016). This tendency can be explained in terms of ability of generalist foragers like Bandicoot rat to exploit wide range of habitats, including openness of canopy and disturbed habitats. Therefore, not all rodents rely on dense, woody vegetation when suitable microhabitat condition is available in open areas. This ability enables them to survive in an urban forest patch, which is quite vulnerable to fragmentation.

6. CONCLUSION AND RECOMMENDATIONS

Based on presented results, Kathmandu Valley as an urbanized area represented moderate diversity of small mammal species. Higher abundance in Ranibari community forest suggested that vegetation cover plays an important role for shaping small mammal communities. Asian house shrew, having adaptable characteristics, was identified as a dominant species in this study. Distribution of small mammals was dependent on distribution of resources in natural environment. Similarly, environmental parameters had a significant role to shape the distribution of small mammals in these forest patches.

On the basis of this study, below listed recommendations have been put forward:

- This study was limited only to three forest patches of Kathmandu valley. In order to depict clear status of small mammals in Kathmandu, it is suggested to carry research on several potential forest fragments.
- It is recommended to conduct further research that is emphasized on small mammals relationship with it's habitat features as well as other mammal species.

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APPENDICES

Appendix 1. Data sheet for morphometric measurement of captured small mammals.

Location: ……

Latitude: …… Longitude: ……

SN	Trap station	Local name	Scientific name	Total length	Tail length	Head body length	Forelimb	Hindlimb	Earlobe length	Sex

Appendix 2. Measurement of environment parameters.

Location: Ranibari community forest

SN	Shrew	BandCo	HR	Open	Forest	Settl	DTR	DTS	DTW
1	1	0	0	1	0	0	97	22	16.4
2	2	0	1	1	0	0	102	52	26.4
3	1	0	0	0	1	0	112	65	46.4
4	2	0	0	0	1	0	89	85	56.4
5	2	0	0	0	1	0	109	83	56.4
6	0	0	0	0	0	0	105	105	76.4
7	0	0	0	0	1	0	115	103	92.1
8	1	0	0	0	1	0	63.4	125	92.1
9	0	0	0	0	1	0	83.4	123	102.1

10	0	0	0	0	1	0	60.1	145	112.1
11	0	0	1	0	1	0	80.1	143	132.4
12	0	1	0	1	0	0	42.5	165	124
13	0	0	0	1	0	0	62.5	163	124
14	1	0	0	0	1	0	48.2	49.8	115
15	1	0	0	0	1	0	68.2	29.8	115
16	2	0	0	1	0	0	39.4	29.8	95.7
17	1	0	0	0	1	0	59.4	9.8	95.7
18	0	0	0	0	1	0	59	7.2	75.7
19	0	0	0	1	0	0	79	27.2	75.7
20	1	0	0	0	1	0	81.4	7.2	55.7
21	0	0	0	1	0	0	101.4	27.2	55.7
22	0	0	0	0	1	0	82.6	7.2	35.7
23	1	0	0	1	0	0	102.6	27.2	35.7
24	0	0	0	0	1	0	81.9	10.7	15.7
25	0	0	0	0	0	0	101.9	30.7	15.7

Location: Swayambhunath hillock

SN	BandCo	HR	Open	Forest	Settl	DTR	DTS	DTW
1	1	1	1	0	0	97	22	16.4
2	1	0	1	0	0	102	52	26.4
3	0	1	0	1	0	112	65	46.4
4	0	0	0	1	0	89	85	56.4

5	0	0	0	1	0	109	83	56.4
6	0	0	0	0	0	105	105	76.4
7	0	0	0	1	0	115	103	92.1
8	0	0	0	1	0	63.4	125	92.1
9	0	0	0	1	0	83.4	123	102.1
10	0	0	0	1	0	60.1	145	112.1
11	0	0	0	1	0	80.1	143	132.4
12	0	0	1	0	0	42.5	165	124
13	0	0	1	0	0	62.5	163	124
14	0	0	0	1	0	48.2	49.8	115
15	0	0	0	1	0	68.2	29.8	115
16	0	0	1	0	0	39.4	29.8	95.7
17	0	0	0	1	0	59.4	9.8	95.7
18	0	0	0	1	0	59	7.2	75.7
19	0	0	1	0	0	79	27.2	75.7
20	0	0	0	1	0	81.4	7.2	55.7
21	0	0	1	0	0	101.4	27.2	55.7
22	0	0	0	1	0	82.6	7.2	35.7
23	0	0	1	0	0	102.6	27.2	35.7
24	0	0	0	1	0	81.9	10.7	15.7
25	0	0	0	0	0	101.9	30.7	15.7

Location: Coronation garden

SN	Shrew	BandCo	HR	Mus	Open	Forest	DTR	DTS
1	0	0	0	0	1	0	32.7	79.1
2	1	0	0	0	1	0	12.7	59.1
3	0	0	0	0	0	1	39.6	59.1
4	0	0	0	0	0	1	19.6	39.1
5	0	0	0	0	0	1	48	79.1
6	0	0	0	0	0	0	28	59.1
7	0	0	0	0	0	1	79.2	99.1
8	0	0	0	0	0	1	59.2	79.1
9	0	0	0	0	0	1	84.3	99.1
10	0	0	0	0	0	1	64.3	129.1
11	2	0	0	0	0	1	85.5	62
12	0	1	0	0	1	0	65.5	42
13	0	0	0	0	1	0	87.5	82
14	0	0	0	0	0	1	67.5	62
15	0	0	0	0	0	1	94.4	102
16	0	0	0	0	1	0	74.4	82
17	0	0	0	0	0	1	91.6	122
18	0	0	0	0	0	1	71.3	102
19	0	0	0	0	1	0	91.3	106.9
20	0	0	0	0	0	1	71.3	86.9
21	1	0	0	0	1	0	89.4	86.9

22	0	0	1	0	0	1	69.4	66.9
23	1	0	0	0	1	0	89	66.9
24	0	0	1	0	0	1	69	46.9
25	1	0	0	1	0	0	79	36.9

Appendix 3. Photographs.

Photo 1: Asian house shrew

Photo 2: Eastern house rat

Photo 3: Irrawaddy squirrel

Photo 4: Taking morphometric data

Photo 5. Vegetation in Coronation garden

Photo 6. A researcher setting trap

Photo 7. House rat

Photo 8. Weight measurement

Photo 9. Cleaning traps

Photo 10. Preparation of bait

Photo 11. Bandicoot rat inside a trap

Photo 12. Animal handling