SPECIES DIVERSITY AND DIET ANALYSIS OF INSECTIVOROUS BAT IN DAUNNE HILL RANGE, CENTRAL NEPAL

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Submitted to

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DECLARATION

I, hereby declare that the work presented in this thesis entitled "**SPECIES DIVERSITY AND DIET ANALYSIS OF INSECTIVOROUS BAT IN DAUNNE HILL RANGE, CENTRAL NEPAL**" 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 author(s) or institution(s).

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This is to recommend that the thesis entitled "**SPECIES DIVERSITY AND DIET ANALYSIS OF INSECTIVOROUS BAT IN DAUNNE HILL RANGE, CENTRAL NEPAL**" has been carried out by Miss Dikshya Poudel for the partial fulfilment of Master's Degree of Science in Zoology with special paper Ecology and Environment. This is her original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institution.

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LETTER OF APPROVAL

On the recommendation of the supervisor, Assistant Professor Dr. Bishnu Prasad Bhattarai, Central Department of Zoology, Tribhuvan University, this thesis submitted by Miss. Dikshya Poudel entitled "**SPECIES DIVERSITY AND DIET ANALYSIS OF INSECTIVOROUS BAT IN DAUNNE HILL RANGE, CENTRAL NEPAL**" is approved for the examination and submitted to the Tribhuvan University in partial fulfillment of the requirements for Master's degree of Science in Zoology with special paper Ecology and Environment.

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CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Dikshya Poudel entitled "**SPECIES DIVERSITY AND DIET ANALYSIS OF INSECTIVOROUS BAT IN DAUNNE HILL RANGE, CENTRAL NEPAL**" has been accepted as a partial fulfillment for the requirements of Master's degree of Science in Zoology specializing in Ecology and Environment.

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LIST OF ABBREVIATIONS

Abbreviated form	Details of abbreviations
GPS	Global Positioning System
IUCN	International Union for Conservation of Nature

ABSTRACT

This study assessed species diversity of the bats along with their foraging habits which is primarily based on guano samples collected from bats, trapped at their feeding and roosting sites in Daunne hill range, central Nepal. Bats were trapped in April and October 2022 using mist nets and scoop net and their guano samples were collected for dietary analysis. Diet is an essential factor to understand the ecology of bats and their conservation. In Nepal, limited information is available regarding the diet of bat. Dietary analysis is very important to interpret the roles of bats as a predator of insects. A total of 63 individuals of bat were trapped belonging to four families. The analysis of 51 guano samples of 10 species of insectivorous bats (*Hipposideros armiger*, *Hipposideros gentilis*, *Rhinolophus pearsoni*, *Pipistrellus tenuis*, *Pipistrellus coromandra*, *Rhinolophus affinis*, *Murina* sp., *Murina cyclotis*, *Rhinolophus pussilus and Pipistrellus javanicus*) revealed five orders of insects such as Coleoptera, Diptera, Lepidoptera, Hemiptera and Hymenoptera. Among them, Coleoptera (54%) was the most important food source for these bats followed by Lepidoptera (24%) and Diptera (19%) in terms of percentage volume in both seasons. A large amount of Diptera content was observed in the diet of *P. javanicus* thus elucidating the role of this species in the control of Diptera. *P. tenuis* and *P. javanicus* showed the highest standardized niche breadth in spring and autumn respectively indicating their broad niche whereas *H. armiger* had lowest niche breadth which revealed that it is specialist in diet. A high degree of diet overlap was observed among bat species which might be due to the availability of prey in the study area. Body size may also be the reason because large bats consume large prey as well as smaller ones whereas medium sized bats forage on smaller prey categories suggesting greater dietary overlap. Molecular techniques should be used to identify prey items up to the species level for calculating precise niche overlap between different species.

1. INTRODUCTION

1.1. Background

Bats are unique mammalian group with sustained flight like birds, inhabiting every continent except Antarctica (Luo et al. 2019). IUCN have recorded the total number of 1394 bat species where 0.6% of them are extinct, 2.2% are considered critically endangered, 6.5% are endangered, 8.8% are vulnerable and 6.6% are categorized as near threatened whereas 16.9 % are data deficient (IUCN 2022). Among them, 148 bat species are reported from southern Asia (Srinivasulu et al. 2021).

Compared to other countries, limited evaluation can be found on species diversity and status of bat in Nepal (Csorba et al. 1999, Hutson and Mickleburgh 2001, Molur et al. 2002, Acharya and Ruedas 2007, Adhikari 2008, Baral and Shah 2008, Acharya et al. 2010, Thapa 2014). In the present context, 55 species of bats have been recorded in Nepal (Thapa 2014, Sharma et al. 2019, Sharma et al. 2021, Dahal et al. 2022 a, Dahal et al. 2022 b).

Foraging habit has essential part in evolutionary biology and ecology because it is crucial for the determination of survival, growth and reproductive success (Kramer and Bernard 2001). Insectivorous bats rely on the availability of ectothermic prey which is also influenced by climatic condition (Burles et al. 2009), eventually effecting diversity of bat food resources (Wang et al. 2010). Abundance of insects such as dipterans and lepidopterans has been predicted to be increased due to more rainfall Frick (2013) which may also inhibit insect flight, decreasing the availability of insects to bats (Anthony et al. 1981). Knowledge on diet is also essential for effective bat conservation which can be acquired through observation and identification of arthropod fragments found in bat guano. Visual identification methods are conducted commonly to identify food species; however, this method is usually accurate only to the order level (Rolfe et al. 2014). Insects, fruits, leaves, flowers, nectar, pollen, seeds, fish, other vertebrates and blood are considered as the diet of bat and this widespread variation of dietary elements makes it unique among other mammals (Patterson et al. 2003).

Insectivorous bat provides one of the most important ecological services that is regulation function (Cleveland et al. 2006) as they suppress arthropods abundance acting as effective biological pest controller (Boyles et al. 2011). Some species can ingest insects equivalent to their body weight in one night. A single colony of *Eptesicus fuscus* ingest about 1.3 million of pest insects each year in Indiana (Whitaker Jr 1995). It reveals that huge number of individuals of bat in foraging activity helps to remove thousands of insects per night from the surroundings (Kurta et al. 1989). Coleoptera, Lepidoptera, Hymenoptera and Hemiptera are some of the insect orders that causes loss in agriculture and insectivorous bats have high capability to control these agricultural pests (Williams-Guillén et al. 2008). Some insects are also considered as a vector of various diseases (Papavero and Guimarães 2000). For example, *Aedes aegypti* under the order Diptera is a vector of dengue and yellow fever viruses (Galati et al. 2015). Insectivorous bats can be important to reduce their population.

Insectivorous bats are considered as generalist in diet with flexible foraging habits leading them to ingest prey in relation to their abundance (Kunz et al. 2011). Conflicting evidence can be found on whether coexisting species of insectivorous bats eat different food. Sedlock et al. (2014) found that various species of insectivorous bat foraging in same habitat tends to consume same prey species whereas Hooper and Brown (1968) revealed that closely related species of insectivorous bat may have to differentiate in some niche dimension in order to reduce competition facilitating coexistence. For instance, Voigt et al. (2010) stated that the differences in wing morphology in Rhinolophid bats of same habitat may promote various foraging habits that facilitates coexistence.

1.2. Rationale

There is limited knowledge about the diversity of bat species that makes prioritizing and planning conservation actions challenging as compared to other large mammals. Due to the lack of intensive survey and monitoring, many bats may still be missing their confirmation in Nepal. There is limited data on the feeding ecology of insectivorous bats, this reflects a general paucity on ecological study of chiropterans in Nepal which sparked the interest to acquire information about the types of insects these bats feed on, because this can have major implications for the biological control of agricultural pests and disease vectors such as mosquitoes. This planned study will help researchers to know the species diversity and dietary composition of bats in Daunne hill range.

1.3. Research objectives

1.3.1. General objective

The general objective of this study was to assess species diversity and diet composition of insectivorous bats in Daunne hill range, central Nepal.

1.3.2. Specific objectives

1. To determine species diversity of bat in the study area.

2. To analyze the diet compositions and niche overlap of insectivorous bats in the study area.

2. LITERATURE REVIEW

2.1. Species diversity of bat

Brian William Hodgson initiated the study on bats of Nepal in 1835. Furthermore, more studies were undertaken by (Scully 1887, Hinton and Fry 1923, Sanborn 1950, Abe 1971, Johnson and Thonglongya 1980, Koopman 1993, Kock 1996). A total number of 38 bat species were recorded from Nepal till 1995 (Suwal et al. 1995). Soon, Bates and Harrison (1997) added more reports on bat species of Nepal making a total of 49 bat species. Molur et al. (2002) reported 51 species of bat from Nepal. Recently, 55 species of bats have been recorded in Nepal (Dahal et al. 2022 a, Dahal et al. 2022 b, Sharma et al. 2019, Sharma et al. 2021, Thapa 2014).

Acharya (2006) studied the distribution of roosting sites and survival threats of bat in the Pokhara valley referencing the population survey at Bat Cave, Pokhara and found that it was roosting site of more than 3000 individuals of two bat species that are *Rhinolophus pussilus* and *Hipposideros armiger*.

Acharya and Ruedas (2007) identified 52 species of bats known to live and breed in Nepal; four from suborder Megachiroptera (Yangochiroptera) and 47 from (Yinpteroptera) within seven families. It is 41% of South Asian and 5% of global bat fauna.

Adhikari (2008) recorded 18 bat species belonging to five families and 11 genera. Out of the identified bat species, three are frugivorous and the remaining 15 are insectivorous. Among them, 11 bat species are listed as Least Concern (LC), five were Near Threatened (NT), one was critically endangered (CR), and another was Endangered (EN).

Baral and Shah (2008) presented 53 bat species in Nepal; however, *Herpiocephalus harpia* which was included in the book is not confirmed. It shows that species diversity of bat is increasing in Nepal and suggest that study on bats should be focused on different unexplored sites.

Acharya et al. (2010) presented 53 species of bat belonging to seven families proving the increasing diversity of bat in Nepal. Morphometric measurements methods were also stated along with the status of bat in Nepal and IUCN.

Thapa et al. (2012) found that 12 species were recorded in ten sites of the survey. The distribution of bat ranges from 1267m to 1992m in Kathmandu valley and found to be rich in the sites at average altitudinal range of 1300 to 1500 m. *Rhinolophous affinis* was found to be widely distributed followed by *Hipposideros armiger*.

According to the checklist prepared by Thapa (2014), 192 species of mammals within 37 families were found in Nepal. Among them, 50 species of bat within seven families were listed.

Boro et al. (2018) recorded two vespertilionid bats namely *Pipistrellus ceylonicus* and *Tylonycteris fulvida* that were identified for the first time from the state of Assam in north-eastern India. The review of existing literature and examinations of museum specimens furnished a checklist of the bat fauna of Assam included 32 species in 17 genera.

Elangovan et al. (2018) conducted visual roost observation such as old, abandoned building, caves, crevices, historical monuments, and forest areas of Uttar Pradesh to assess the distribution of bats. 15 species with three species of suborder Megachiroptera and the remaining 12 species belonging to suborder Microchiroptera were recorded.

Debata and Palita (2019) conducted roost survey on 76 sites in Odisha and recorded 16 species of bats within seven families. Among them, insectivorous bats were maximum with 12 species over frugivorous and carnivorous. Cave tourism and hunting for ethno-zoological practices and cutting down of roosting trees were observed as major threats to bats.

Sharma et al. (2019) documented the first record of dawn bat *Eonycteris spelaea* from western Nepal using mist net within Banpale forest, Pokhara. This is also the fourth record of *Eonycteris spelaea* occurring in Nepal.

Chakravarty et al. (2020) reported thirty-five species from 15 genera and five families using mist net and roost survey. Out of the thirty-two species, nine species recorded unique echolocation calls for the first time in the world. *Myotis cf. frater* was a new find in the whole subcontinent of India. The remaining eight species, *Tadarida teniotis, Murina leucogaster, Murina aurata, Murina cyclotis, Myotis cf. frater, Myotis cf. annectans, Mirostrellus joffrei, Arielulus circumdatus* and *Eptesicus tatei* were new find for the whole west region of the Himalayas.

Bhattarai et al. (2021) identified 55 individuals belonging to eight species within eight genera and four families, using mist nets in the Banpale forest. Trapping locations near less disturbed forest edges and water resources were found to have higher bat diversity compared to highly disturbed areas such as landslides and logging areas.

Rai et al. (2021) recorded ten species of bats from Dolakha district, using mist-netting and roost survey. Echolocation signals of three species was described for the first time in Nepal. This study also reports the presence of *Myotis formosus* for the fifth time in Nepal.

Sharma et al. (2021) reported the first record of *T. teniotis* from Nepal and presented its possible elevational movement in the Himalaya. Acoustic surveys were conducted in the Kali Gandaki. During autumn, the activity was recorded only at 2100 to 2500m and varied significantly from winter activity while *T. teniotis* was observed at both elevational zones during winter.

Dahal et al. (2022) reported first record of *Coelops frithii* during a cave survey in the Makwanpur District. A colony with 15 individuals was found roosting in a narrow and moist cavity of the Saraswati cave. The species was identified by its small size and characteristic funnel shaped ears and externally invisible and nodular tail.

Dahal et al. (2022) recorded first record *Harpiocephalus harpia* during survey of bat in 2016 and 2021. Three individuals of the large tube-nosed bats within subfamily Murininae were caught in Central and Eastern Nepal and identified as *Harpiocephalus harpia* based on its morphological characters.

Srinivasulu et al. (2021) prepared a checklist of bats including 150 bat species within ten families. It included 21 Rhinolophidae, 16 Hipposideridae, 79 Vespertilionidae, five Miniopteridae, four Molossidae, six Emballonuridae, three Rhinopomatidae, two Megadermatidae, single Rhinonycteridae and 13 Pteropodidae.

In high elevation, the species richness and functional diversity of bat species decreased whereas phylogenetic diversity remained unchanged. Low functional dispersion was observed at lowest elevation despite high species and functional richness which suggest niche packing mechanism. The decrease in functional richness, dispersion and divergence at high elevation was consistent with the patterns seen because of environmental filtering. The patterns here are driven by the absence of rhinolophids bats (Chakravarty et al. 2021).

Chakravarty et al. (2023) stated that small niche with high overlap accompanied increase in species richness in low elevation. But high elevation assemblage demonstrates large niche breadth with low overlap among the functional group members. Edge space foraging, trawling and active gleaning bats have the highest niche breadth while passive gleaning bats are mostly specialist showing low overlap with other groups.

2.2. Diet of insectivorous bat

Malla (2000) conducted the diet analysis of insectivorous bats of Nagarjun cave which was first in Nepal. On the study, Percentage volume of Coleoptera and Lepidoptera varies in different species such as Coleoptera was higher in *Hipposideros* spp. but Lepidoptera in *Rhinolophus* spp. Others were Orthroptera, Hymenoptera, Hemiptera and Diptera in the diet of bats of Nagarjun cave, Kathmandu.

Williams (2001) presented that *Hipposiderus* spp. consumed Diptera mostly in British and Irish range followed by Lepidoptera, Neuroptera, Araneidae and Acari. Sphaeroceridae was found to be the most abundant family followed by Teichoceridae, Mycetophilidae and Scathophagidae.

Pokhrel (2013) presented food habits of bats of Mahendra Cave and Nagarjun Cave through fecal analysis. The comparison between percentage volume of the insect order in two caves were shown in which Coleoptera and Orthoptera were major in Mahendra Cave whereas Diptera was major in Nagarjun Cave. In Mahendra Cave, the average percentage of frequency of Coleopteran food items was high followed by Orthoptera in spring and vice versa in autumn. In Nagarjun Cave, Diptera was highest in both seasons.

Srinivasulu and Srinivasulu (2005) showed the dietary composition of the Black-bearded Tomb Bat from two different habitats which was then analyzed following fecal pellet analysis method. 11 insect orders and spiders (Araneidae) were identified as part of the diet. Coleoptera, Homoptera, Lepidoptera, Hemiptera, Orthoptera, Odonata and Araneidae, were the prey of choice of forest bats, while the semi-urban bats chose Lepidoptera, Coleoptera, Diptera, Orthoptera, Odonata, Hemiptera, Araneidae and Homoptera.

Zhang et al. (2005) examined food habits of *Tylonycteris pachypus* and *T. robustula* by fecal analysis in 2 counties of Guangxi, South China. The diet of *T. robustula* included seven orders of insects: Hymenoptera (62.3% by volume), Diptera (29.6%), Coleoptera (6.0%), Hemiptera (1.5%), and traces of Orthoptera, Trichoptera, and Ephemeroptera. The diet of *Tyloncycteris pachypus* included all the main orders consumed by *T. robustula* (53.4%, 29.0%, 13.4%, 2.1% respectively) and three other orders: Homoptera, Blattodea, and Embioptera. There was a clear seasonal variation from spring to autumn in the diet of *Tylonycteris pachypus* between the different geographical areas studied.

Andrianaivoarivelo et al. (2006) reported that in eastern Madagascar, the percentage volume of Hemiptera and Lepidoptera were similar in the diet of bat species, pooled across season but significant differences were found for Diptera and Coleoptera. However, *Mops leucostigma* had the highest volume of Diptera and M. jugularis of Coleoptera. Hemiptera were an important food source for all species during both seasons whereas Coleoptera were prevalent in the diet only during the summer.

Lacki et al. (2007) looked at bat diets and prey consumption using fecal samples from bats trapped in mist nets. 12 insect orders along with 18 taxonomic families of insects, were identified. Lepidoptera were the dominant prey of four of the five species of bats examined, with Coleoptera the dominant prey of big brown bats.

Aguiar and Antonini (2008) examined food habits of *Myotis nigricans* and *Eptesicus furinalis* by fecal analysis. The diet of *Eptesicus furinalis* included six orders of insects: Coleoptera (5/7 by items presence), Lepidoptera and Hymenoptera (3/7), Diptera, Hemiptera and Homoptera (1/7). Bat's predatory action on species of Scarabeidae, Hesperiidae, Sphingidae and Saturniidae families supports their use for pest control in agriculture.

Ma et al. (2008) stated that studying the diet of insectivorous bats can provide important insights into their foraging behaviors and ecological constraints they face. Each species has different preferences for food items. *Rhinolophus ferrumequinum*, choose to catch nocturnal, actively flying insects mostly moths (Lepidoptera) to a less Diptera, beetles (Coleoptera), and flying ants and termites (Hymenoptera). *Myotis chinensis* prefer to glean, large terrestrial prey of the order Coleoptera and Orthoptera, whereas *Murina leucogaster* consume smaller, diurnal Coleoptera.

Feldhamer et al. (2009) collected data on the diet of eight species of insectivorous bats from forest sites throughout southern Illinois. We analyzed prey remains in fecal pellets of 305 individuals to assess diet similarity among species and relationships between bat body mass and prey diversity and hardness. Big brown bats and evening bats that primarily ate hard-bodied beetles (Coleoptera). Regional differences in diets were minimal within the same assemblage of bat species in southern Indiana.

Graclik and Wasielewski (2012) investigated the diet of *Myotis myotis* through fecal analysis of nine hundred droppings in western Poland. The bat droppings contained three taxonomic orders namely Coleoptera, Lepidoptera, and Diptera and in addition to that two other groups of arthropods (Chilopoda: Lithobiidae and Arachnida: Araneae) were also present.

Bhartiy and Elangovan (2021) assessed seasonal prey availability and diet composition of the *Scotophilus kuhlii* in various districts of Uttar Pradesh. Fecal and insect samples were collected seasonally using sweep nets between 1800 and 1900 h. The analysis revealed that *Scotophilus kuhlii* fed on Coleoptera, Diptera, Hymenoptera, Isoptera, Orthoptera, Odonata, Blattodae, Lepidoptera, and Hemiptera, identified from legs, antennae, and wings/elytra in fecal pellets. There is seasonal variation based on insect abundance and isolated insect remnants at foraging grounds. Thus, *Scotophilus kuhlii* plays a vital role as a pest control agent and is a voracious feeder.

Ashrafi et al. (2011) showed that the occurrence of many fragments of both diurnal and flightless insects in *P. auratus* diet revealed that this species mostly gleans prey from substrates. *P. austriacus* and *P. macrobullaris* are aerial feeders. *P. auritus* has a much broader diet whereas the latter two species have narrow trophic niches. Comparison of intraspecific and interspecific niche overlaps in *P. auritus* and *P. macrobullaris* in sympatry indicates dietary niche partitioning between these two species.

Salinas-Ramos et al. (2015) stated that diet of bats showed a moderate overlap with the highest value in wet season between *Pteronotus parnellii* and *Pteronotus personatus*. Higher dietary overlap between species was found during the same seasons than within any single species across seasons suggesting that diets of the three species are driven more by prey availability than by any predator-specific characteristic.

There are limited scientific studies on bats and are conducted on their status and distribution. Researchers are still in the stage of identification of bat species. The survey on bats have not been carried out in Daunne hill range till now. Very few studies on the diet of insectivorous bats have been conducted in Nepal.

3. MATERIALS AND METHODS

3.1. Study area

The study was conducted in three sites spread over two districts, Bardaghat and Daunne Devi located in Parasi whereas Dumkibaas is in Nawalpur district of Nepal. The forest of these areas was subtropical forest (mostly short grassland, mixed forest, and riverine forest), dominated by Sal *Shorea robusta* with Saj *Terminalia tomentosa* as the co dominant species. Some associated species are *Terminalia alata*, *Terminalia bellirica, Semecarpus anacardium* and *Rhus* species (Subedi et al. 2009). Parasi district have annual minimum and maximum temperature ranging from 17.5◦c to 29.6◦c respectively (Pandey et al. 2020).

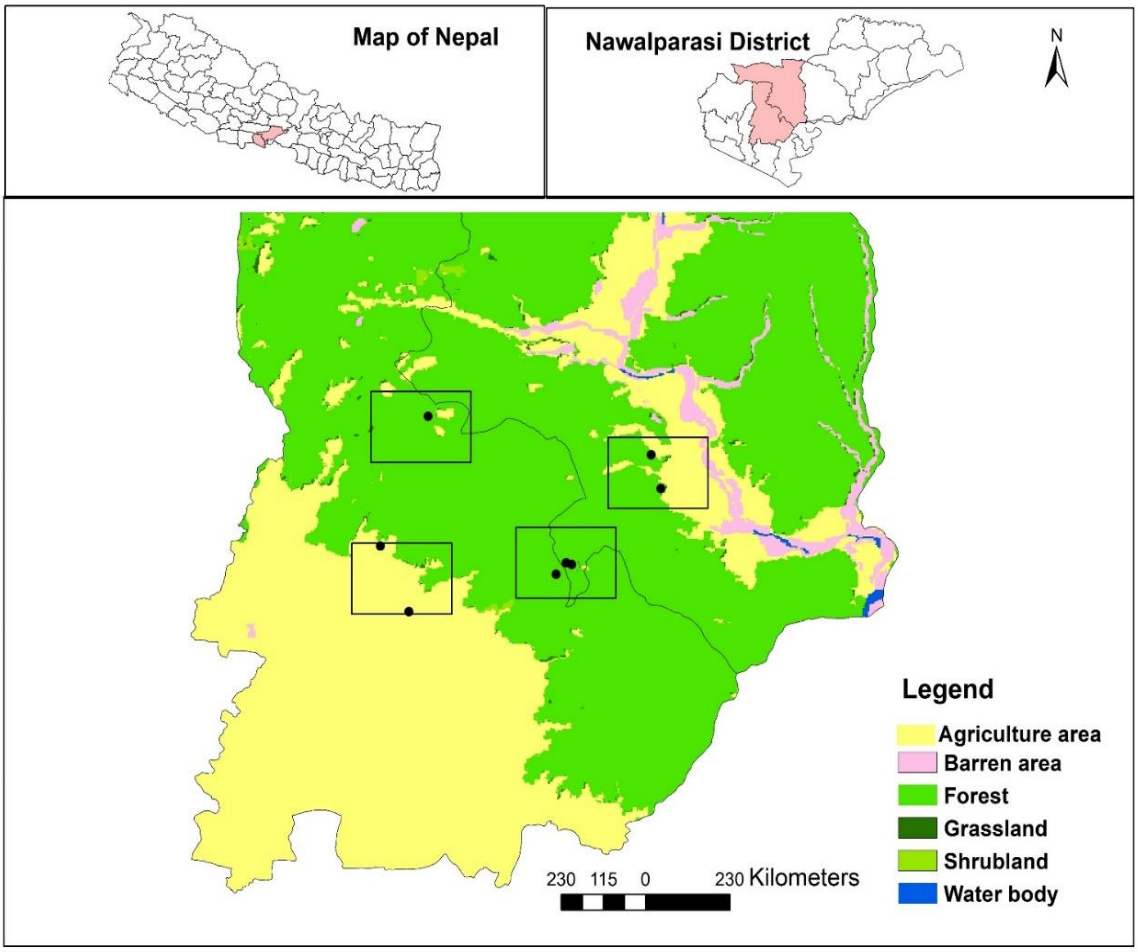


Figure 1. Study area (Bardaghat and Binayi Tribeni Municipality)

3.2. Data collection

3.2.1. Field work

3.2.1.1. Preliminary survey

A preliminary survey was conducted from 15th - 20th February 2022. During that time, the previously recorded and potential distribution sites of bats were identified by questioning knowledgeable local people and field visit. A single roosting site was identified from this survey by visiting informed and probable sites to confirm the presence of bats.

3.2.1.2. Field survey

The field survey was conducted from 24th - 29th April and 1st - 2nd October and 13th - 16th October 2022 covering 12 days for field work. The blocks of 2km x 3km were made in places which have similar types of vegetation and habitat like canopy forest, old tree cavities, streams, ponds in three sites. ArcMap 10.8 tools were used to overlay 2km x 3km geographical grid cells on the study area. GPS (Garmin Etrex 10) was used to record the location of trapped bats. The same blocks and sites were used in the second survey.

3.2.1.3. Bat Trapping

Various techniques have been developed to make bat sampling more feasible (Flaquer et al. 2007). Roost survey is the most common method, but it is limited to the species roosting in caves and man-made structures (Lourenço and Palmeirim 2004). In this study, a single roosting site, cave was surveyed. Ultrasound detectors are good non-invasive methods for bat studies. However, excessive cost as well as lower detectability for bats with high frequency hampers the choice of this approach. Therefore, mist net is one of the most used trapping techniques for bats (Waldien and Hayes 1999). Mist net and scoop net were used to trap bats in this study to take morphometric measurements and photographs of the individuals similar to various studies (Bhattarai et al. 2021, Akmali et al. 2022).

a.) Mist netting

Two varied sizes (3m, 6m) of ecotone mist net with 14 mm mesh size were used for bats trapping in the field. Mist nets were installed from early evening (5 pm) to 10 pm in study sites such as streams and walking trails. Three people attended the nets continuously and extracted the bats immediately upon capture in order to avoid pre-mature death due to strangling and escape by chewing the net.

b.) Scoop netting

A cave survey was done once in each season during the day. A scoop net was used to capture bats in the cave.

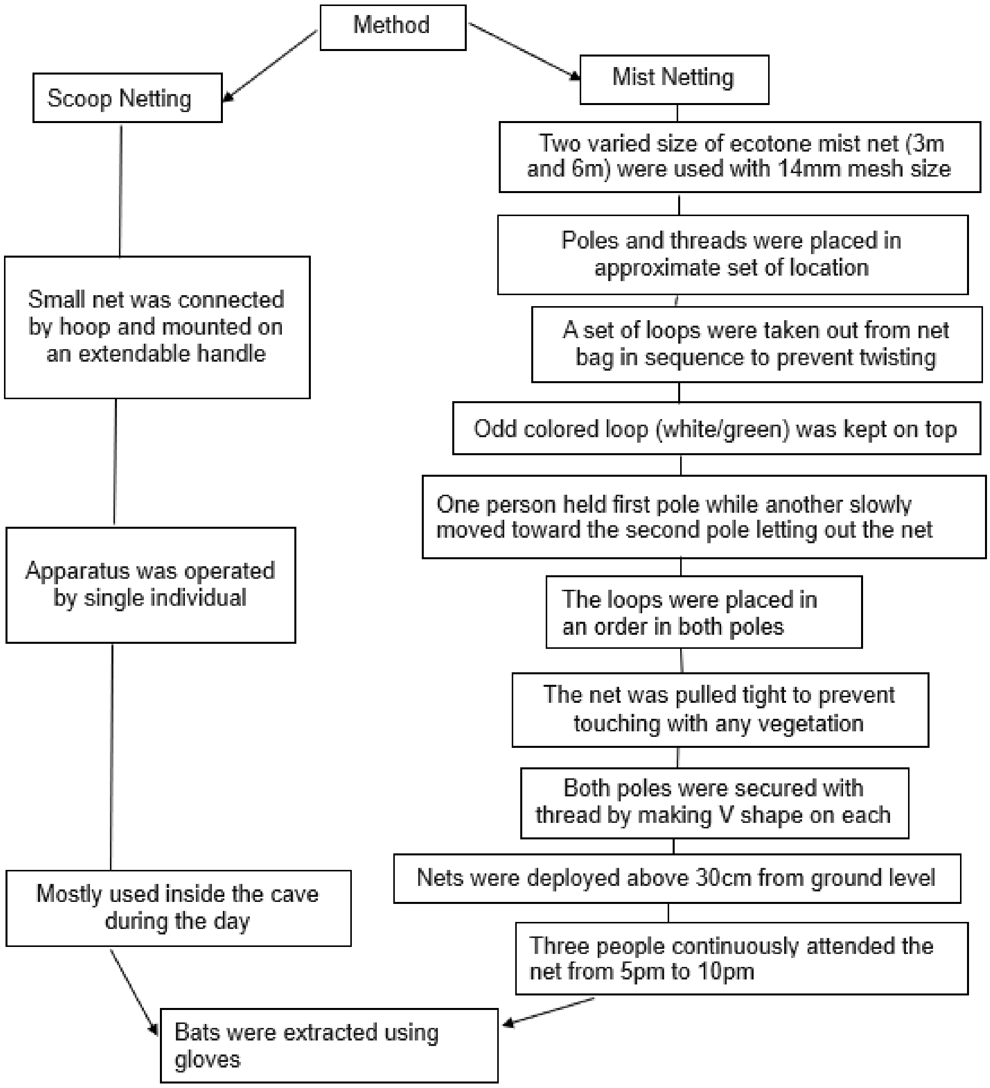


Figure 2. Methods for trapping bat

3.2.2. Species identification

Morphometric features such as length of forearm and sexes of bat were recorded following standard techniques of Bates and Harrison (1997) and physical appearances were also observed using the information from (Acharya et al. 2010). The sexes of bats were identified by examination of their external genitalia. Males have clearly visible penis. Axillary nipples were found in both male and female on the upper chest. Nipples of adult females are more prominent. Vernier caliper of 0.01mm accuracy was used to measure forearm length from the extremity of the elbow to the extremity of carpus with the wing folded excluding the jaw. A few closeup photographs were taken with EOS 1100D Canon for identification of trapped individuals of bats with minimal disturbance. Identification of bat to species level was done with the aid of Bats of Nepal: A field guide (Acharya et al. 2010) and (Srinivasulu et al. 2021). Nets were shifted to new locations every day for six days in each season to improve capture by avoiding easy detection of nets by bats.

Figure 3. Forearm length of bat

3.2.3. Guano collection and laboratory analysis

Guano analysis is one of the most reliable methods to estimate the diet of bats because the fragments of insects such as wings and legs remain partially intact in bat feces (Zhang et al. 2005). Bats were caught from mist net and placed into clean and soft cotton bags, one in each for two to three hours. They were released after collection of guano without any stress. Each guano sample was collected and then placed into the zip lock bags to preserve in a dry state using silica gel. Coding such as name of the species, collection date, time and location were written in the front of zip lock bag with the help of permanent CD marker. The guano samples were then brought to the lab for further analysis.

51 guano samples were collected for diet analysis. Lab work was done in May and November 2022 in the laboratory of the Central Department of Zoology. Guano samples were analyzed using the method of Whitaker (Whitaker Jr 1988). Each sample was soaked in the petri dish containing 70% ethanol and teased apart using dissecting needles under the stereo microscope (Best Scope, BS-3020T). Ectoparasites (Acari) and hair found in the droppings, resulting from grooming, were excluded from the analysis. Histological slides were prepared by dehydrating the samples in alcohol and mounted using DPX. Microphotographs were also taken to confirm the identification of insect remains. The taxonomic keys available for the Coleoptera, elytra (Triplehorn and Johnson 2004), antennae and legs (Pokhrel and Budha 2014, Nemes and Price 2015) Diptera, antennae (McAney et al. 1991) and wings (Kirk-Spriggs and Sinclair 2017), body of Hemiptera and wing of Hymenoptera (Triplehorn and Johnson 2004) and Lepidoptera, scales (Sin et al. 2020) and (Painter et al. 2009) were used. Some textbooks (Vanemden 1965, Distant 1977, Borror et al. 1981) were also used to identify insect residuals. All parts were identified up to the lowest achievable taxonomic level.

3.2.4 Data analysis

The gathered information was organized, structured, and entered into Microsoft Excel for further analysis.

3.2.4.1. Species diversity

Shannon wiener diversity index was calculated to understand species diversity in different trapping sites (Wiener and Shannon 1949).

Shannon index (H´) = – Σ pi (*lnpi*)

Where pi = S/N

S = Number of individuals of one species

N = Total number of individuals trapped

ln = Logarithm to base e

ni = Number of individuals

N = Total number of individuals

Pielou's evenness (J) was calculated to compare the actual diversity value (the Shannon index, H) to the maximum possible diversity value (when all species are equally common, H_{max} = *lnS*).

$J = \frac{\mathrm{H}}{\mathrm{Hmax}}$ or $J = \frac{H}{lnS}$

Where, H = Shannon index value(observed)

H_{max} = Maximum possible diversity value

S = Total number of species

3.2.4.2. Diet analysis

Diet analysis is done by using the formulae given by (Whitaker Jr 1988). A visual estimate was made for each category using five pellets per bat as one sample. Individual bats were used as sample units rather than individual pellets to avoid pseudo replication.

Percentage volume of each food category was calculated by using formulae:

$$\%\mathrm{Volume} = \frac{\text{Sum of individual volume}}{\text{Total volume of sample}} \text{ x } 100$$

In order to determine the degree of selectivity of the prey categories consumed by bats, Levin's measure of niche breadth described by (Krebs 1999) was used to measure the uniformity of the resources being utilized. The equation is,

$$B = \frac{1}{\Sigma Pi^2}$$

where, B = Levin's measure of niche breadth

Pi= proportion of individuals using resources

(Hurlbert 1978) suggested the measure given below for standardized niche breadth.

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

Where, Bs= Levin's standardized niche breadth

n= total number of prey categories for the species

Standardized niche breadth shows diversity of prey consumed by bat species and ranges from 0-1. 0 means species have limited choice of prey. Narrow niche (<0.4) which indicate specialized taxa that favors specific prey category and 0.75-1 indicates broad niche and generalist taxa, prefers prey abundant across the environment. The value from 0.4-0.75 indicates the taxa with moderate niche breadth.

Pianka's niche overlap

Niche overlap between the most common bat species was calculated by using the formulae given by (Pianka 1973). The value ranges from 0-1.

$$O_{jk} = \frac{(\sum P_{ij} P_{ik})}{\sqrt{\sum P_{ij}^2 \sum P_{ik}^2}}$$

Where Ojk = Pianka's measure of overlap between species j and k

Pij=proportion by number that resource i is of the total resources used by species j

Pik= proportion by number that resource i is of the total resources used by species k.

The overlap values range from 0 (no overlap) to 1(complete overlap) and are defined low (0.0-0.39), intermediate (0.40-0.60) and high (0.61-1.00) (Grossman 1986).

Non-metric Multidimensional Scaling (NMDS) ordination was used to compare the diet overlap between bat species using the Bray-Curtis Distance Metric (Hammer et al. 2001). To visualize and interpret the variation between species, this approach uses rank order value. Differences in diet composition were assessed using Similarity Analysis (ANOSIM). It is a nonparametric procedure used to calculate dissimilarity among and within species groups. Past 4.0 was used to prepare the final graph (Hammer et al. 2001). The ANOSIM provides two measures, statistic R and significance. Statistic R is a measure that compares the mean of ranked dissimilarities between groups to the mean of ranked dissimilarities within groups. Statistic R values indicate similarities and differences within and between groups. The value of R ranges from -1 to +1; values close to zero indicate an even distribution, and no difference between groups. Positive values suggest that similarity is occurring more within groups instead of between groups (McCoy 2020). Values less than 0.05 are considered statistically significant.

4. RESULTS

4.1. Species diversity

A total of 11 species of bats were trapped belonging to four families. The maximum trapped bat species belonged to the family Vespertilionidae (5) followed by Rhinolophidae (3), Hipposideridae (2) and Pteropodidae (1). *Hipposideros armiger* was the most trapped bat species followed by *Cynopterus sphinx* and *Hipposideros gentilis*. Each of *Rhinolophus pusillus*, *Pipistrellus javanicus* and *Rhinolophus affinis* were trapped once. Trap percentage of bats was highest in Bardaghat (66.66%) followed by Daunne (28.56%) and Dumkibaas (4.75%). Species diversity of bat was highest in Bardaghat (H´=1.57) followed by Daunne (H´=1.461) and Dumkibaas (H´=0.8032). Evenness was highest in Dumkibaas (J=1.116) followed by Bardaghat (J=0.96) and Daunne (J=0.86) (Table 1).

Morphometric analysis showed that three bat species; *H. armiger* (FA= 89.18–94.05), *R. pearsoni* (FA= 51.75–52.85) and *H. gentilis* (FA= 40.24–41.12) were trapped by using scoop net in the cave whereas eight bat species *C. sphinx* (FA= 68.13–73.15), *P. tenuis* (FA= 28.49–29.61), *Murina* sp. (FA= 36.91–39.9), *M. cyclotis* (FA= 32.62–33.23), *P. coromandra* (FA= 30.59–32.1), *R. affinis* (FA= 52.81), *R. pusillus* (FA= 37.3) *and P. javanicus* (FA= 30.77) were trapped in mist net (Table 2).

Among the bat species trapped, all species except *H. gentilis* (NT) fall under Least Concern (Table 3).

Table 1. Comparison of species abundances and bat diversity in three different trapping sites at Daunne hill range; A, B and C. Note: S= spring, A= autumn, m = total male trapped, f = female trapped, j = juvenile and 0 represents no capture

Species	**Bardaghat**		**Daunne**		**Dumkibaas**		**Total**	**Relative Abundance**
	S	**A**	**S**	**A**	**S**	**A**		
Hipposideros armiger	7	6	0	0	0	0	13(m=8, f=5)	20.63
Rhinolophous pearsoni	4	3	0	0	0	0	7(m=2, f=5)	11.11
Hipposideros gentilis	6	4	0	0	0	0	10(m=3, f=7)	15.87
Cynopterus sphinx	5	4	0	0	2	0	11(m=3, f=6, j=2)	17.46
Rhinolophous affinis	0	0	1	0	0	0	1(m=1)	1.58
Murina sp.	0	0	1	7	0	0	8(m=3, f=4)	12.69
Pipistrellus tenius	3	0	0	0	0	0	3(m=1, f=2)	4.76
Murina cyclotis	0	0	0	4	0	0	4(m=2, f=2)	6.34
Rhinolophous pusillus	0	0	0	1	0	0	1(f=1)	1.58
Pipistrellus coromandra	0	0	3	1	0	0	4(m=3, f=1)	6.34
Pipistrellus javanicus	0	0	0	0	0	1	1(m=1)	1.58
Total	25	17	5	13	2	1	63	100
Trap percentage (%)	39.68	26.98	7.93	20.63	3.17	1.58		
Diversity (H´)	1.57		1.461		0.803			
Evenness (J)	0.96		0.86		1.11			

Table 2. Forearm (FA) length of trapped bats with R (Range value), M (Mean value) and SD (Standard deviation) and remarks with key identifying features.

Capture Method	**Species**	**Forearm Length(mm) M ± SD(R)**	**Identifying features**
Scoop netting	*Hipposideros armiger* (Hodgson,1835)	91.62 ± 2.439 (89.18–94.05)	presence of four supplementary leaflets in nose leaf with outer leaflet distinctively smaller
Scoop netting	*Rhinolophus pearsoni* (Horsefield,1851)	52.304 ± 0.55 (51.75–52.85)	pelage is long, soft wooly texture and mid chest brown color
Scoop netting	*Hipposiderus gentilis* (Andersen,1918)	40.68 ± 0.439 (40.24–41.12)	dorsal pelage with mid deep brown hair roots. ventral pelage is pale throughout
Mist netting	*Cynopterus sphinx* (Vahl,1797)	70.64 ± 2.508 (68.13–73.15)	presence of white ear margin on both sides of ear
Mist netting	*Pipistrellus tenuis* (Temminck,1840)	29.056 ± 0.56 (28.49–29.61)	pinnae and membranes are dark throughout
Mist netting	*Murina* sp.	38.002 ±1.09 (36.91–39.9)	plagiopatagium is attached to the base of the first toe
Mist netting	*Murina cyclotis* (Dobson,1872)	32.93 ± 0.308 (32.62–33.23)	dorsal pelage with more orange and less reddish hue with pale grey hair roots
Mist netting	*Pipistrellus coromandra* (Gray,1838)	31.35 ± 0.753 (30.59–32.1)	pelage color is uniform brown above while paler below
Mist netting	*Rhinolophus affinis* (Horsefield, 1823)	52.81	ear is short, horseshoe is broad
Mist netting	*Rhinolophus pusillus* (Temminck,1834)	37.3	dorsal pelage is light brown to deep brown with pale hair.
Mist netting	*Pipistrellus javanicus* (Gray,1838)	30.77	dorsal pelage with light frosting of paler brown hair tips

Table 3. Species of bat trapped in Daunne hill range. Notes: LC indicates Least Concern; NT means Near Threatened (Source: Bats of Nepal)

S. N.	Common Name	Species Name	Nepali Name	Family	IUCN Status	National Status
1	Great Himalayan Leaf-nosed Bat	*Hipposideros armiger*	Thulo golopatre chamero	Hipposideridae	LC	LC
2	Andersen's leaf-nosed bat	*Hipposideros gentilis*	Gudikhaa ne golopatre chamero	Hipposideridae	LC	NT
3	Pearson's horseshoe bat	*Rhinolophous pearsoni*	Pearson ko ghodnale chamero	Rhinolophidae	LC	LC
4	Intermediate horseshoe bat	*Rhinolophous affinis*	Majhaula ghodnale chamero	Rhinolophidae	LC	LC
5	Least horseshoe bat	*Rhinolophous pusillus*	Sano ghodnale chamero	Rhinolophidae	LC	LC
6		*Murina* sp.		Vespertilionidae		
7	Round eared tube nosed bat	*Murina cyclotis*	Golokane	Vespertilionidae	LC	LC
8	Least Pipistrelle	*Pipistrellus tenuis*	Sano Chamero	Vespertilionidae	LC	LC
9	Javan Pipistrelle	*Pipistrellus javanicus*	Java ko chamero	Vespertilionidae	LC	LC
10	Coromandel Pipistrelle	*Pipistrellus coromandra*	Buchhe chamero	Vespertilionidae	LC	LC
11	GreaterShort -nosed Fruit Bat	*Cynopterus sphinx*	Nepte chamero	Pteropodidae	LC	LC

4.2. Dietary composition

A total of 52 individuals of insectivorous bats were captured out of which guano was extracted only from 51 bats and the remaining one did not defecate.

4.2.1. Dietary profile of individual species

H. armiger: It was the most abundant bat species in the study area with 12 guano samples. Out of 12, seven were collected in spring and the remaining five in autumn. Coleoptera (65%) was the most consumed prey category i.e., insect order followed by Lepidoptera (18%), Diptera (12%) and Hemiptera (6%) in spring season. In autumn, Coleoptera (50%) was the most consumed insect order followed by Lepidoptera (25%) Diptera (13%) and Hemiptera (13%). Increase in the consumption of Lepidoptera and Diptera was observed in autumn. The guano samples of this species consist of four insect orders such as Coleoptera, Diptera, Lepidoptera and Hemiptera (Appendix I. Photograph 18,21).

H. gentilis: *H. gentilis* was the second most abundant insectivorous bat with ten guano samples. Out of five prey categories, three were consumed by this species. The most dominating prey category was Coleoptera (50%) in both seasons followed by Lepidoptera and Diptera in autumn whereas Lepidoptera and Diptera were found in equal percentage in spring (Photograph 19).

Murina sp.: Out of eight guano samples collected in the study area, one was from spring and the remaining seven were from autumn. Coleoptera was the most dominant prey category in both seasons followed by Lepidoptera (Photograph 26).

M. cyclotis: Total number of guano samples collected from this species was four from autumn. Seven prey items were found from this species. Coleoptera was the highest consumed prey order followed by Diptera (Photograph 27).

P. tenuis: Three guano samples of *P. tenuis* were collected in spring. The diet of this species consists of five prey items belonging to two prey categories. Coleoptera was the dominant prey order followed by Diptera (Photograph 28, 23).

P. coromandra: Four guano samples of *P. coromandra* were collected; three from spring and one from autumn. Coleoptera was the most ingested prey order followed by Lepidoptera and Diptera in both seasons (Photograph 29).

P. javanicus: Only single guano sample of this species was collected in autumn. Diptera was the most consumed prey (50%) category followed by Coleoptera (Photograph 22, 24).

R. pearsoni: A total of seven guano samples of *R. pearsoni* were collected from the study area. The diet of this species consists of 14 prey items. Coleoptera was the most consumed prey category followed by Lepidoptera, Diptera and Hymenoptera in spring whereas in autumn, Lepidoptera was the most consumed prey followed by Coleoptera and Diptera (Photo 20, 25).

R. affinis: It was one of the least abundant bats with a single guano sample. A total of three prey items were found. Among which, Coleoptera was the most abundant prey category followed by Lepidoptera (Photograph 32).

R. pussilus: Only one guano sample of this species was collected from autumn. Three prey items were identified through analysis. Among them, Coleoptera was the most abundant prey order followed by Diptera (Photo 30, 31) (Figure 4, 5).

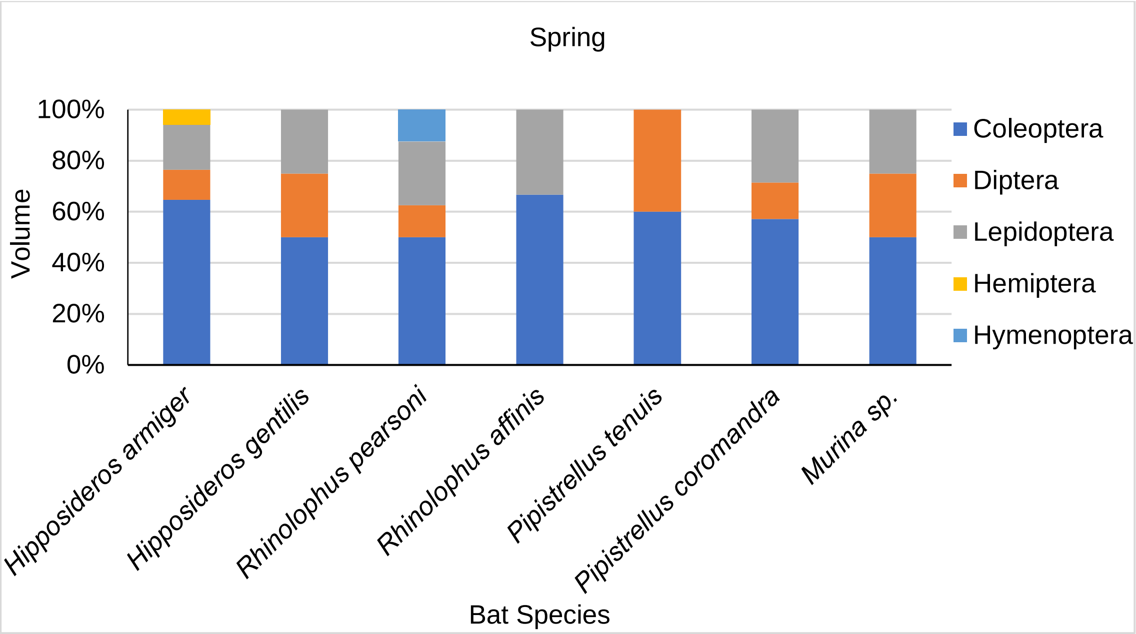


Figure 4. Percentage volume of prey categories in the diet analysis of bat species in Daunne hill range in spring season.

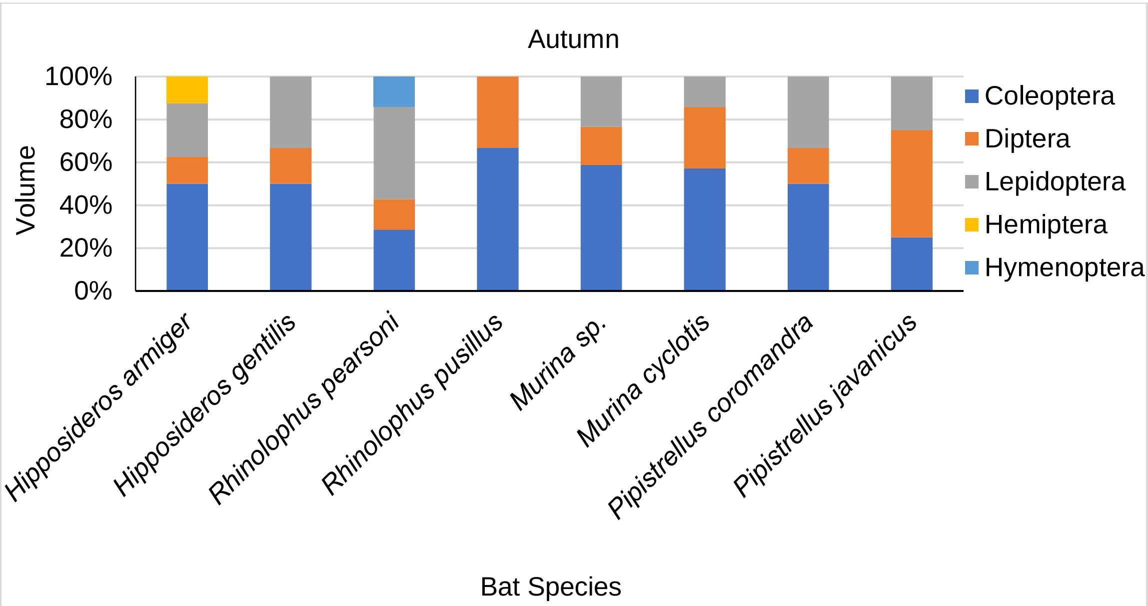


Figure 5. Percentage volume of prey categories in the diet analysis of bat species in Daunne hill range in autumn season.

4.2.2. Dietary niche overlap

In spring, *P. tenuis* (0.92) was found to have highest standardized niche breadth followed by *H. gentilis* (0.83) and Murina sp. indicating their broad niche which reveals that they prey on wide range of prey categories whereas the lowest was 0.38, noticed in *H. armiger* revealed that it is specialized bat whose diet depends maximum on Coleoptera among five prey categories in the study area. In the case of Autumn, the highest standardized niche breadth was found in *P. javanicus* (0.83) followed by *R. pussilus* (0.94) whereas lowest was observed in *H. armiger* (0.64), revealed that the diet of *H. armiger* depends maximum on Coleoptera compared to other prey categories (Figure 6). The value of Pianka's dietary niche overlap index (Ojk=0.98) was highest between *H. gentilis* and *Murina* sp. due to the highest consumption of Coleoptera followed by Lepidoptera. *H. gentilis* and *R. pearsoni* (Ojk= 0.96) showed overlap in the consumption of Coleoptera.

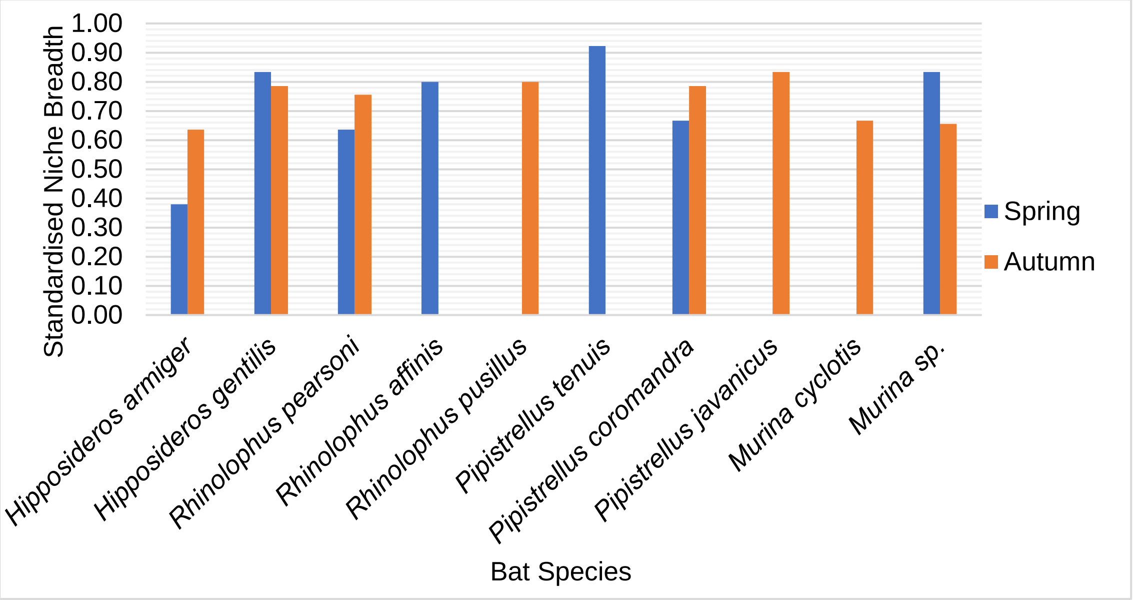


Figure 6. Dietary standardized niche breadth of the bat species in Daunne hill range in Spring and Autumn.

In Non-Metric Multidimensional Scaling (NMDS), species with similar diet preferences are ordinate closer than those further apart. From ANOSIM, R=0.025, p=0.31 it means there is no significant difference between diet of bat species and dietary overlap can be seen among the five common bat species trapped in both seasons (Figures 7,8).

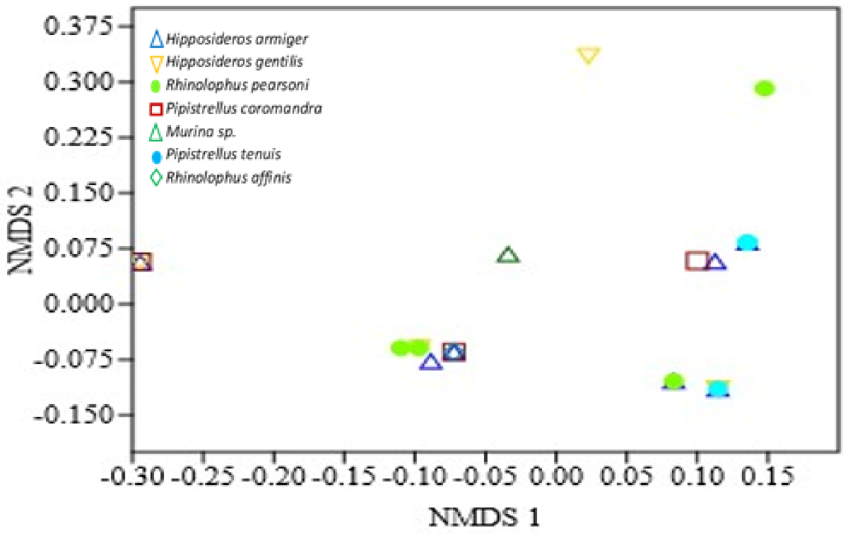


Figure 7. Nonmetric Multidimensional scaling (NMDS) ordination of diet overlaps between seven trapped bat species in spring season. Notes: Each symbol represents one individual**.** Symbol that are ordinated closer to one another are likely to be more similar than those further apart. Stress level: 0.17

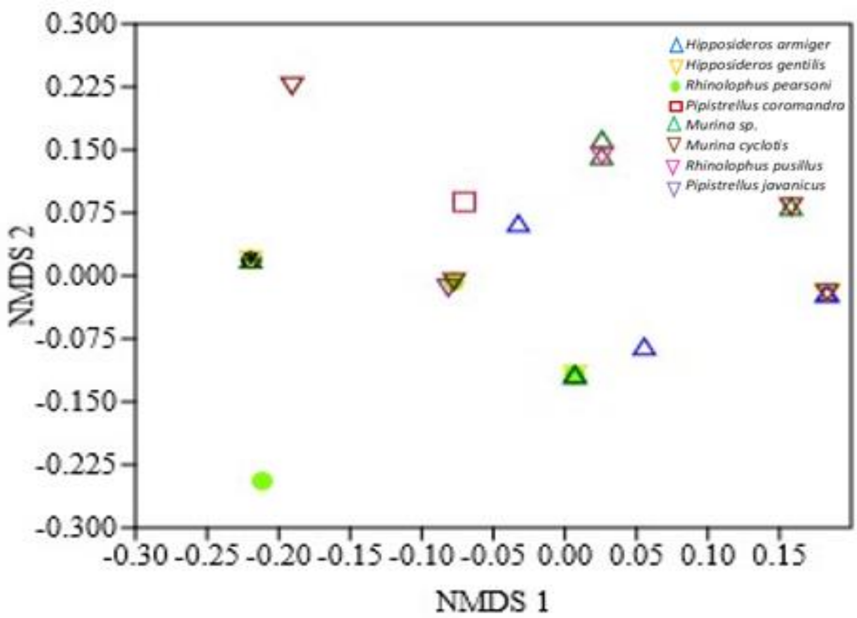


Figure 8. NMDS ordination of diet overlaps for eight trapped bat species in autumn with stress level 0.18. Note: Each symbol represents one individual.

5. DISCUSSION

5.1. Species diversity

The total number of 11 species and 63 individuals of bats were recorded using mist net and scoop net in the study area. *Murina* sp. and *M. cyclotis* were found in primary forest. *P. coromandra*, *P. tenuis* and *P. javanicus* were trapped using mist net in this study and these are the only three species of Pipistrellus known to Nepal (Thapa and Thapa 2010). According to Acharya et al. (2010), these three species are found on both primary and secondary forest as well as on agricultural landscape which aligns with the findings in this study.

H. armiger, *H. gentilis* and *R. pearsoni* are mainly cave dwellers as described by Molur et al. (2002) and those were trapped using scoop net at the entrance and cavities of the only cave in this study. All of these species are widespread in Nepal, roosting on varieties of sites such as caves, tunnels, and old houses (Acharya et al. 2010). Kingsada et al. (2011) recorded *R. affinis* in primary forest similar to this study.

C. sphinx was the only fruit bat which was trapped from two sites (Bardaghat and Dumkibaas). These study sites were surrounded by different fruiting trees such as *Mangifera indica, Bombax ceiba, Litchi chinensis* which are the most preferable diet for fruit bats in Nepal (Sharma et al. 2016). *Schima wallichi* and *Musa* sp. were also abundant in the study sites that are considered as the favored roosts for such tent making bat (Acharya et al. 2010). Hence, the availability of food resources and roosting vegetation could be the reason for high capture of this species.

5.2. Diet consumption

This study gives some valuable baseline knowledge about the diet of 10 insectivorous bat species from Daunne hill range. Coleoptera was the most consumed prey category which is not surprising because it is the largest insect order consisting of one third of all insect species. Rolfe et al. (2014) stated that Coleoptera provides food sources of high quality for bats that can ensure to meet their nutritional needs which might be the additional reason behind its high consumption. It is impossible to identify the relationship between food eaten and availability of each insect species because the relative proportion of biomass of various insect order was not studied; whether they consume coleoptera in proportion to their abundance or especially select this category.

Coleoptera was the most consumed prey category followed by Lepidoptera in the diet of *H. armiger*, contrary to the findings of Weterings et al. (2015) in which percentage volume of Hemiptera was highest followed by Lepidoptera and Coleoptera but similar to Feng (2001) and Zubaid (1988). Large bats with high bite force are more likely to consume insects with thick exoskeleton such as Coleoptera (Andreas et al. 2012) which may be the reason behind its highest consumption.

In this study, Lepidoptera was the most consumed prey category followed by Coleoptera in the diet of *R. pearsoni* similar to Jiang et al. (2008). However, the opposite of above was found in the diet of *R. affinis* which aligns with the findings of Jiang et al. (2013) in which Coleoptera was the most consumed prey category. The diet composition of *R. pussilus* was predominated by Coleoptera which was similar to results of (Wei et al. 2006). Coleoptera consists of beetles that can produce sound while in flight and feeding. Sometimes sound produced by beetles can be heard from a few feet away (Borror et al. 1981). This sound can attract bat and might be one of the reason behind preferable hunt of Coleoptera. Bogdanowicz et al. (1999) stated that the bite performance also influences diet composition of bats mainly within Rhinolophidae as bigger food items will require higher bite force (Aguirre et al. 2003).

The dietary composition of *P. coromandra* is predominated by Coleoptera in both seasons followed by Lepidoptera and Diptera which is somewhat similar to the findings of (Misra and Elangovan 2016) that consists of Coleoptera as its only diet. The dietary analysis of *P. javanicus* and *P. tenuis* was not conducted prior to this study. However, many studies have shown that bats of the genus Pipistrellus fed on various prey categories. For example, Feldman et al. (2000) showed that in Israel, *Pipistrellus kuhlii* consumed on prey categories like Lepidoptera, Coleoptera, Diptera, Hemiptera, Hymenoptera and Homoptera where Diptera was dominant prey category followed by Lepidoptera and Coleoptera. According to Benda et al. (2006), in Syria, Auchenorrhyncha and Coleoptera were dominant prey category in the diet of *P. kuhlii* followed by Hymenoptera and Lepidoptera in one location whereas Coleoptera was dominant prey category followed by Lepidoptera and Heteroptera in another. Goiti et al. (2003) reported Diptera as the most consumed diet of *Pipistrellus kuhlii* followed by Lepidoptera. These results revealed that the diet of Pipistrellus bats is not dominated by a single prey category. The difference in feeding habits may be due to the energy needs of the bat species and the abundance of various insect prey categories and their availability as prey where these bat species forage. Whitaker and Karataş (2009) also concluded that these bat species can be treated as generalist and opportunistic feeders.

The dietary analysis of *M. cyclotis* and *Murina* sp. was not conducted before this study. Apart from several taxonomic publications and occurrence records, little is known about the diet of these species. Several studies showed that bats of the genus Murina feeds on different insect orders. Ma et al. (2008) reported Coleoptera as the most dominant insect order consumed by *Murina leucogaster* whereas Heim et al. (2021) presented Lepidoptera as the most consumed insect order by *Murina ussuriensis*. The ecological condition and behavioral aim of insectivorous bat is closely linked with shape of echolocation signal (Schnitzler and Kalko 2001). *M. cyclotis* is also considered as slow flying bats and often observed hovering. Coleoptera, the most consumed prey by *M. cyclotis* in the findings of this study consists of family Scarabaeidae, which are found on substrate close to ground and remains stationary at night which may also be the reason of its high consumption.

According to the Optimal Foraging Theory (OFT), bats should consume prey based on their availability when no limit to ingestion was present and should be opportunistic in their feeding habitats. It suggests that forager should prefer prey with high nutritional value to lower nutritional value when prey with higher nutritional value is readily available (Sih and Christensen 2001). This might also be the reason for the difference in prey consumption.

5.3. Dietary niche overlap

The 10 species of insectivorous bat present in the study area had a high degree of dietary overlap. Diets of all species mostly comprised similar types of prey with Coleoptera, Diptera and Lepidoptera as dominant prey categories. Their foraging habits and consumption of similar types of prey could be due to their foraging approach. In addition, five bat species were found in both seasons. The high dietary niche overlap among the bat species might be explained by prey availability and their foraging habits. *H. armiger* and *R. pearsoni* consumed four out of five prey categories which suggests these species can consume most of the possible prey found in the surroundings. This might be because of the body size as large bat (*H. armiger*) consume large prey as well as smaller ones (Andreas et al. 2012) whereas medium sized bats forage on almost similar prey categories suggesting greater dietary overlap (Ojk=0.95). A complete niche overlap was observed between *H. gentilis* and *Murina* sp. These are medium sized bats that forage in slow fight and are well adapted for detecting arthropods due to their short call in highly cluttered habitats (Schnitzler et al. 2003) which might be the reason for the highest overlap.

In Spring, the highest niche breadth was observed in *P. tenuis* followed by *H. gentilis* and *Murina* sp. This finding suggested that *P. tenuis* is the most generalist in diet among six other species. *H. armiger* have narrow niche; 0.38 in spring and 0.64 in autumn. It is considered as a specialist in diet, traditionally defined as an animal consuming at least 60% of prey from a single order. The difference in dietary preference might be the reason for the coexistence of these bat species in similar environments (Pianka 1973). In addition, the difference in niche breadth and the absence of particular prey categories of some species also facilitates coexistence (Hooper and Brown 1968).

6. CONCLUSIONS AND RECOMMENDATION

6.1. Conclusions

A single species of frugivorous bat was trapped showing lower diversity of frugivorous bat compared to insectivorous bat in the study area. Vespertilionidae is a dominant family with five bat species followed by Rhinolophidae. The most dominant prey category was Coleoptera, preferred by most of the species except *P. javanicus*. Species of bat trapped in the study area have almost similar niche breadth; *P. tenuis* and *P. javanicus* possessed broader dietary niche in spring and autumn respectively. All bat species in the study area depend upon similar types of prey which might be due to prey availability in the study area. The high dietary niche overlap among bat species suggests that there is intense competition for food resources.

6.2. Recommendation

- Prey items should be identified up to the species level using molecular techniques to calculate precise niche overlap between different species.

7. REFERENCES

Abe, H. 1971. Small mammals of central Nepal. Journal of the faculty of agriculture, Hokkaido University **56**:367-423.

Acharya, P. R. 2006. Distribution of roosting and survival threats of bat in Pokhara valley with reference to species and population survey at Chamere Gupha.

Acharya, P. R., Adhikari, H., Dahal, S., Thapa, A. and Thapa, S. 2010. Bats of Nepal. A field guide. Small Mammals Conservation and Research Foundation (SMCRF), Kathmandu **116**:1-114.

Acharya, P. R. and Ruedas, L. A. 2007. The bat fauna of Nepal: A current conspectus. Bat Net Newsletter **8**:16-19.

Adhikari, H. 2008. Bat species richness and their distribution in Pokhara valley of Nepal. The Initiation **2**:43-48.

Aguiar, L. and Antonini, Y. 2008. Diet of two sympatric insectivores bats (Chiroptera: Vespertilionidae) in the Cerrado of Central Brazil. Revista Brasileira de Zoologia **25**:28-31.

Aguirre, L., Herrel, A., Van Damme, R. and Matthysen, E. 2003. The implications of food hardness for diet in bats. Functional Ecology **17**:201-212.

Akmali, V., Abedini, S. and Fard, Z. M. 2022. Bat fauna and conservation assessment of Kurdistan caves, Iran. Subterranean Biology **42**:79-95.

Andreas, M., Reiter, A. and Benda, P. 2012. Dietary composition, resource partitioning and trophic niche overlap in three forest foliage-gleaning bats in Central Europe. Acta Chiropterologica **14**:335-345.

Andrianaivoarivelo, A. R., Ranaivoson, N., Racey, P. A. and Jenkins, R. K. 2006. The diet of three synanthropic bats (Chiroptera: Molossidae) from eastern Madagascar. Acta Chiropterologica **8**:439-444.

Anthony, E., Stack, M. and Kunz, T. 1981. Night roosting and the nocturnal time budget of the little brown bat, *Myotis lucifugus*: effects of reproductive status, prey density, and environmental conditions. Oecologia **51**:151-156.

Ashrafi, S., Beck, A., Rutishauser, M., Arlettaz, R. and Bontadina, F. 2011. Trophic niche partitioning of cryptic species of long-eared bats in Switzerland: implications for conservation. European Journal of Wildlife Research **57**:843-849.

Baral, H. S. and Shah, K. 2008. Wild mammals of Nepal. Himalayan Nature.

Benda, P., Andreas, M., Kock, D., Lucan, R., Munclinger, P., Nova, P., et al. 2006. Bats(Mammalia: Chiroptera) of the Eastern Mediterranean. Bat fauna of Syria: distribution, systematics, ecology. Acta Societatis Zoologicae Bohemicae **70**:210-211.

Bhartiy, S. K. and Elangovan, V. 2021. Seasonal prey availability and diet composition of Lesser Asiatic Yellow House Bat *Scotophilus kuhlii* Leach, 1821. Journal of Threatened Taxa **13**:19002-19010.

Bhattarai, P. K., Sharma, B., Neupane, A., Kunwar, S. and Dhungana, P. 2021. Bat diversity in the Banpale forest, Pokhara, Nepal during spring season. Journal of Threatened Taxa **13**:18479-18489.

Bogdanowicz, W., Fenton, M. and Daleszczyk, K. 1999. The relationships between echolocation calls, morphology and diet in insectivorous bats. Journal of Zoology **247**:381-393.

Boro, A. R., Saikia, P. K. and Saikia, U. 2018. New records of bats (Mammalia: Chiroptera) from Assam, northeastern India with a distribution list of bat fauna of the state. Journal of Threatened Taxa **10**:11606-11612.

Borror, J., Delong, M. and Triplehorn, A.1981. An introduction to the study of insect. Saunders College Publishing, Philadaphia, New York.

Boyles, J. G., Cryan, P. M., McCracken, G. F. and Kunz, T. H. 2011. Economic importance of bats in agriculture. science **332**:41-42.

Burles, D., Brigham, R., Ring, R. and Reimchen, T. 2009. Influence of weather on two insectivorous bats in a temperate Pacific Northwest rainforest. Canadian Journal of Zoology **87**:132-138.

Chakravarty, R., Mohan, R., Voigt, C. C., Krishnan, A. and Radchuk, V. 2021. Functional diversity of Himalayan bat communities declines at high elevation without the loss of phylogenetic diversity. Scientific reports **11**:22556.

Chakravarty, R., Radchuk, V., Managave, S. and Voigt, C. C. 2023. Increasing species richness along elevational gradients is associated with niche packing in bat assemblages. Journal of Animal Ecology **92**:863-874.

Chakravarty, R., Ruedi, M. and Ishtiaq, F. 2020. A recent survey of bats with descriptions of echolocation calls and new records from the western Himalayan region of Uttarakhand, India. Acta Chiropterologica **22**:197-224.

Cleveland, C. J., Betke, M., Federico, P., Frank, J. D., Hallam, T. G., Horn, J., et al. 2006. Economic value of the pest control service provided by Brazilian free-tailed bats in south-central Texas. Frontiers in Ecology and the Environment **4**:238-243.

Csorba, G., Kruskop, S. and Borissenko, A. 1999. Recent records of bats (Chiroptera) from Nepal, with remarks on their natural history.

Dahal, D. R., Thapa, S., Baral, S., Thapa, T. B. and Singh, N. B. 2022. First record of East Asian tailless leaf-nosed bat (*Coelops frithii*) from Nepal and extension of its global range. Mammalia **86**:521-523.

Dahal, D. R., Thapa, S., Ghimire, R., Csorba, G. and Singh, N. B. 2022. First records of the Hairy-winged bat (*Harpiocephalus harpia*) from Nepal. Journal of Bat Research & Conservafion Volume **15**:49.

Debata, S. and Palita, S. K. 2019. Bat fauna (Mammalia: Chiroptera) of southern Odisha along the Eastern Ghats, India. Proceedings of the Zoological Society, Springer.

Distant, W. 1977. Fauna of British India: Rhynchota vol 5: Heteroptera. Today and Tomorrow's Printers and Publishers, New Delhi, India

Elangovan, V., Mathur, V., Kumar, M. and Priya, Y. S. 2018. Diversity and Conservation of Chiropteran Fauna. Indian Hotspots: Vertebrate Faunal Diversity, Conservation and Management **1**:57-87.

Feldhamer, G. A., Carter, T. C. and Whitaker, J. O. 2009. Prey consumed by eight species of insectivorous bats from southern Illinois. The American Midland Naturalist **162**:43-51.

Feldman, R., Whitaker, J. O. and Yom-Tov, Y. 2000. Dietary composition and habitat use in a desert insectivorous bat community in Israel. Acta Chiropterologica **1**.

Feng, J. 2001. Studies on echolocating behavior and ecology in bats. Jinlin Science and Technology Publishing House, Changchun, China.

Flaquer, C., Torre, I. and Arrizabalaga, A. 2007. Comparison of sampling methods for inventory of bat communities. Journal of Mammalogy **88**:526-533.

Frick, W. F. 2013. Acoustic monitoring of bats, considerations of options for long-term monitoring. Therya **4**:69-70.

Galati, E. A., Camara, T. N. d. L., Natal, D. and Chiaravalloti-Neto, F. 2015. Mudanças climáticas e saúde urbana. Revista USP 79-90.

Goiti, U., Vecin, P., Garin, I., Saloña, M. and Aihartza, J. R. 2003. Diet and prey selection in Kuhl's pipistrelle *Pipistrellus kuhlii* (Chiroptera: Vespertilionidae) in south-western Europe. Acta Theriologica **48**:457-468.

Graclik, A. and Wasielewski, O. 2012. Diet composition of *Myotis myotis* (Chiroptera, Vespertilionidae) in western Poland: results of fecal analyses. Turkish Journal of Zoology **36**:209-213.
Grossman, G. D. 1986. Food resource partitioning in a rocky intertidal fish assemblage. Journal of Zoology **1**:317-355.
Hammer, Ø., Harper, D. A. and Ryan, P. D. 2001. PAST: Paleontological statistics software package for education and data analysis. Palaeontologia electronica **4**:9.
Heim, O., Puisto, A. I., Sääksjärvi, I., Fukui, D. and Vesterinen, E. J. 2021. Dietary analysis reveals differences in the prey use of two sympatric bat species. Ecology and Evolution **11**:18651-18661.
Hinton, M. and Fry, T. 1923. Report No. 37: Nepal. Bombay Natural History Society's Mammal Survey of India, Burma, and Ceylon. Journal of the Bombay Natural History Society **29**:399-428.
Hooper, E. T. and Brown, J. H. 1968. Foraging and breeding in two sympatric species of Neotropical bats, genus Noctilio. Journal of Mammalogy **49**:310-312.
Hurlbert, S. H. 1978. The measurement of niche overlap and some relatives. Ecology **59**:67-77.
Hutson, A. M. and Mickleburgh, S. P. 2001. Microchiropteran bats: global status survey and conservation action plan. IUCN.
Jiang, T., Feng, J., Sun, K. and Wang, J. 2008. Coexistence of two sympatric and morphologically similar bat species *Rhinolophus affinis* and *Rhinolophus pearsoni*. Progress in Natural Science **18**:523-532.
Jiang, T., Lu, G., Sun, K., Luo, J. and Feng, J. 2013. Coexistence of *Rhinolophus affinis* and *Rhinolophus pearsoni* revisited. Acta Theriologica **58**:47-53.
Johnson, D. and Thonglongya, K. 1980. Mammals from Nepal.
Kingsada, P., Douangboubpha, B., Ith, S., Furey, N., Soisook, P., Bumrungsri, S., et al. 2011. A checklist of bats from Cambodia, including the first record of the intermediate horseshoe bat *Rhinolophus affinis* (Chiroptera: Rhinolophidae), with additional information from Thailand and Vietnam. Cambodian Journal of Natural History **2011**:49-59.
Kirk-Spriggs, A. H. and Sinclair, B. J. 2017. Manual of Afrotropical Diptera **1**.
Kock, D. 1996. Fledermäuse aus Nepal (Mammalia: Chiroptera). Senckenbergiana biologica **75**:15-22.
Koopman, K. 1993. Order Chiroptera. 137–241. Smithsonian Institution Press. Washington, DC.
Kramer, L. D. and Bernard, K. A. 2001. West Nile virus infection in birds and mammals. Annals of the New York academy of sciences **951**:84-93.
Krebs, C. J.1999. Ecological Methodology. Addison. Welsey Educational Publishers, Inc., Menlo Park, CA.
Kunz, T. H., Braun de Torrez, E., Bauer, D., Lobova, T. and Fleming, T. H. 2011. Ecosystem services provided by bats. Annals of the New York academy of sciences **1223**:1-38.
Kurta, A., Bell, G. P., Nagy, K. A. and Kunz, T. H. 1989. Energetics of pregnancy and lactation in freeranging little brown bats (*Myotis lucifugus*). Physiological Zoology **62**:804-818.
Lacki, M. J., Johnson, J. S., Dodd, L. E. and Baker, M. D. 2007. Prey consumption of insectivorous bats in coniferous forests of north-central Idaho. Northwest Science **81**:199-205.

Lourenço, S. I. and Palmeirim, J. M. 2004. Influence of temperature in roost selection by *Pipistrellus pygmaeus* (Chiroptera): relevance for the design of bat boxes. Biological conservation **119**:237-243.

Luo, B., Santana, S. E., Pang, Y., Wang, M., Xiao, Y. and Feng, J. 2019. Wing morphology predicts geographic range size in vespertilionid bats. Scientific reports **9**:4526.

Ma, J., Liang, B., Zhang, S. and Metzner, W. 2008. Dietary composition and echolocation call design of three sympatric insectivorous bat species from China. Ecological Research **23**:113-119.

Malla, R. 2000. Diet analysis of *Hiposideros armiger* and *Rhinolophus pusillus* (Microchiroptera) of Nagarjuna Cave. Central Department of Zoology. Kathmandu, Nepal. Tribhuvan University.

McAney, C., Shiel, C., Sullivan, C. and Fairley, J. 1991. The analysis of bats droppings. Mammal Society. Occasional Publication **1448**.

Misra, P. K. and Elangovan, V. 2016. Light and scanning electron microscopic studies on food habit analysis of insectivorous bats. Advances in Life Sciences **5**:3649-3654.

Molur, S., Marimuthu, G., Srinivasulu, C., Mistry, S., Hutson, A. M., Bates, P. J., et al. 2002. Status of South Asian Chiroptera. Conservation Action Management Plan (CAMP) Workshop Report, Zoo Outreach Organisation, 320pp.

Nemes, S. N. and Price, D. L. 2015. Illustrated Keys to the Scarabaeinae (Coleoptera: Scarabaeidae) of Maryland. Northeastern Naturalist **22**:318-344.

Painter, M., Chambers, C., Siders, M., Doucett, R., Whitaker, J., JO and Phillips, D. 2009. Diet of spotted bats (*Euderma maculatum*) in Arizona as indicated by fecal analysis and stable isotopes. Canadian Journal of Zoology **87**:865-875.

Pandey, A., Bista, D. R., Bhandari, T., Panta, H. K. and Devkota, S. 2020. Profitability and resource-use efficiency of sugarcane production in Nawalparasi west district, Nepal. Cogent Food & Agriculture **6**:1857592.

Papavero, N. and Guimarães, J. H. 2000. The taxonomy of Brazilian insects vectors of transmissible diseases (1900-2000)-Then and now. Memórias do Instituto Oswaldo Cruz **95**:109-118.

Patterson, B. D., Willig, M. R. and Stevens, R. D. 2003. Trophic strategies, niche partitioning, and patterns of ecological organization. Bat ecology **9**:536-557.

Pianka, E. R. 1973. The structure of lizard communities. Annual review of ecology and systematics **4**:53-74.

Pokhrel, S.2013. Food Habits of Insectivorous Bats of Mahendra and Nagarjun Caves, Nepal. Department of Zoology.

Pokhrel, S. and Budha, P. B. 2014. Key to identify insects from droppings of some insectivorous bats of Nepal. Journal of Institute of Science and Technology **19**:129-136.

Rai, V., Thapa, S., Chalise, P. and Shah, K. B. 2021. Record of bats and their echolocation calls from southern Dolakha, central Nepal. Mammalia **85**:557-567.

Rolfe, A. K., Kurta, A. and Clemans, D. L. 2014. Species-level analysis of diets of two mormoopid bats from Puerto Rico. Journal of Mammalogy **95**:587-596.

Salinas-Ramos, V. B., Herrera Montalvo, L. G., León-Regagnon, V., Arrizabalaga-Escudero, A. and Clare, E. L. 2015. Dietary overlap and seasonality in three species of mormoopid bats from a tropical dry forest. Molecular Ecology **24**:5296-5307.

Sanborn, C. C. 1950. A Nepal record of the Long-eared Bat (*Plecotus homochrous* Hodgson). Chicago Academy of Sciences.

Schnitzler, H.-U. and Kalko, E. K. 2001. Echolocation by insect-eating bats: we define four distinct functional groups of bats and find differences in signal structure that correlate with the typical echolocation tasks faced by each group. Bioscience **51**:557-569.

Schnitzler, H.-U., Moss, C. F. and Denzinger, A. 2003. From spatial orientation to food acquisition in echolocating bats. Trends in Ecology & Evolution **18**:386-394.

Scully, J. 1887. On the Chiroptera of Nepal. Journal of the Asiatic Society of Bengal **56**:233-259.

Sedlock, J. L., Krüger, F. and Clare, E. L. 2014. Island bat diets: does it matter more who you are or where you live? Molecular Ecology **23**:3684-3694.

Sharma, B., Baniya, S., Subedi, A., Gyawali, K., Panthee, S., Ghimire, P., et al. 2019. First record of dawn bat *Eonycteris spelaea* (Dobson, 1871)(Mammalia: Chiroptera: Pteropodidae) from western Nepal. Journal of Bat Research & Conservafion Volume **11**:1.

Sharma, B., Chakravarty, R. and Acharya, P. R. 2021. The first record of European free-tailed Bat, *Tadarida teniotis* Rafinesque, 1814, and note on probable elevational movement from Nepal. Journal of Asia-Pacific Biodiversity **14**:248-253.

Sharma, S., Luhach, A. K. and Sinha, S. 2016. An optimal load balancing technique for cloud computing environment using bat algorithm. Indian J Sci Technol **9**:1-4.

Sih, A. and Christensen, B. 2001. Optimal diet theory: when does it work, and when and why does it fail? Animal behaviour **61**:379-390.

Sin, S., Chhorn, S., Doeurk, B., Hak, K., Ith, S., Phauk, S., et al. 2020. Diet preferences of insectivorous bats (Mammalia. Cambodian Journal of Natural History 69.

Srinivasulu, B. and Srinivasulu, C. 2005. Diet of the black-bearded tomb bat Taphozous melanopogon Temminck, 1841 (Chiroptera: Emballonuridae) in India. Zoos' Print J **20**:1935-1938.

Srinivasulu, C., Srinivasulu, A. and Srinivasulu, B. 2021. Checklist of the bats of South Asia (v1. 5). Website: https://threatenedtaxa. org/index. php/JoTT/checklists/bats/southasia [Date of publication: 01 January 2021].

Subedi, G., Khatiwada, B., Bhattarai, S. and Acharya, K. P. 2009. Forest composition, fuelwood harvest and regeneration status in four community forests of Central Nepal. Scientific World **7**:53-58.

Suwal, R., Verheugt, W. and YONZON, P. 1995. Enumeration of Mammals of Nepal Biodiversity Profiles Project Publica tion No. 6. Department of National Parks and wildlife Conservation, Kathmandu.

Thapa, A. and Thapa, S. 2010. A short note on chiropteran status from Kailash cave, Syangja district, Western Nepal. Lifescience Journo-Magazine **2**:1-7.

Thapa, S. 2014. A checklist of mammals of Nepal. Journal of Threatened Taxa **6**:6061-6072.

Thapa, S., Shrestha, S., Dahal, S., Daniel, B. and Singh, N. B. 2012. Monitoring and conservation of bats in the Kathmandu Valley, Nepal. Asian Journal of Conservation Biology **1**:1-4.

Triplehorn, C. and Johnson, N.2004. Introduction to the Study of Insects, ; Thomson Brooks. Cole Press: Belmont, CA, USA.

Vanemden, F.1965. Fauna of India, Diptera. Baptist Mission Press, Calcutta, India.

Voigt, C. C., Schuller, B.-M., Greif, S. and Siemers, B. M. 2010. Perch-hunting in insectivorous Rhinolophus bats is related to the high energy costs of manoeuvring in flight. Journal of Comparative Physiology B **180**:1079-1088.

Waldien, D. L. and Hayes, J. P. 1999. A technique to capture bats using hand-held mist nets. Wildlife Society Bulletin 197-200.

Wang, J., Gao, W., Wang, L., Metzner, W., Ma, J. and Feng, J. 2010. Seasonal variation in prey abundance influences habitat use by greater horseshoe bats (*Rhinolophus* *ferrumequinum*) in a temperate deciduous forest. Canadian Journal of Zoology **88**:315-323.

Wei, L., Zhou, S.-y., Zhang, L.-b., Liang, B., Hong, T.-y. and Zhang, S.-y. 2006. Characteristics of echolocation calls and summer diet of three sympatric insectivorous bats species. Zoological Research **27**:235.

Weterings, R., Wardenaar, J., Dunn, S. and Umponstira, C. 2015. Dietary analysis of five insectivorous bat species from Kamphaeng Phet, Thailand. Raffles bulletin of zoology **63**.

Whitaker, J. O. and Karataş, A. 2009. Food and feeding habits of some bats from Turkey. Acta Chiropterologica **11**:393-403.

Whitaker Jr, J. 1988. Food habits analysis of insectivorous bats. Ecological and behavioral methods for the study of bats. 171-189.

Whitaker Jr, J. O. 1995. Food of the big brown bat *Eptesicus fuscus* from maternity colonies in Indiana and Illinois. American Midland Naturalist 346-360.

Wiener, W. and Shannon, C. 1949. The mathematical theory of communication. Urbana, Illionis: University of Illionis **290**.

Williams-Guillén, K., Perfecto, I. and Vandermeer, J. 2008. Bats limit insects in a neotropical agroforestry system. science **320**:70-70.

Williams, C. A.2001. The winter ecology of *Rhinolophus hipposideros*, the lesser horseshoe bat. Open University.

Zhang, L., Jones, G., Rossiter, S., Ades, G., Liang, B. and Zhang, S. 2005. Diet of flat-headed bats, *Tylonycteris pachypus* and *T. robustula*, in Guangxi, South China. Journal of Mammalogy **86**:61-66.

Zubaid, A. 1988. Food habits of *Hipposideros armiger* (Chiroptera: Rhinolophidae) from Peninsular Malaysia. Mammalia **52**:585-588.

APPENDICES

Appendix I. List of Photographs

Species of bat trapped in Daunne hill range, central Nepal.

Photograph 1. *Hipposideros armiger*

Photograph 2. *Cynopterus sphinx*

Photograph 3. *Rhinolophus pearsoni*

Photograph 4. *Pipistrellus coromandra*

Photograph 5. *Hipposideros gentilis*

Photograph 6. *Rhinolophus affinis*


Photograph 7. *Murina* sp.


Photograph 8. *Rhinolophus pussilus*


Photograph 9. *Pipistrellus javanicus*


Photograph 10. *Murina cyclotis*


Photograph 11. *Pipistrellus tenuis*

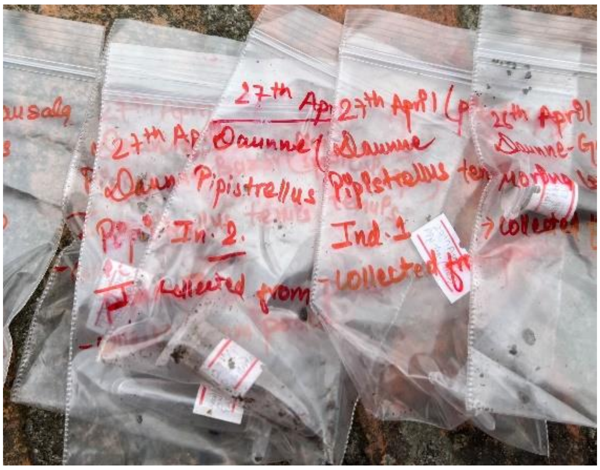
Photograph 12. Mist net setup for trapping bat in Badipidit, Bardaghat.

Photograph 13. Two individuals of bats trapped on mist net in secondary forest of Daunne.

Photograph 14. Extracting a bat from mist net for morphometric measurement and guano sample collection.

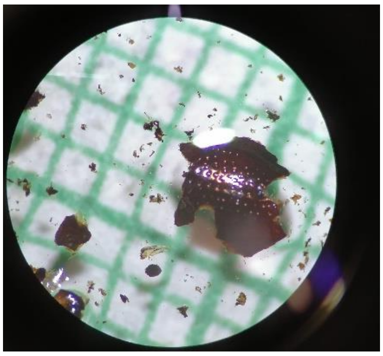
Photograph 15. Collecting guano sample from a cotton pouch.

Photograph 16. Preservation of guano sample in Eppendorf tube.

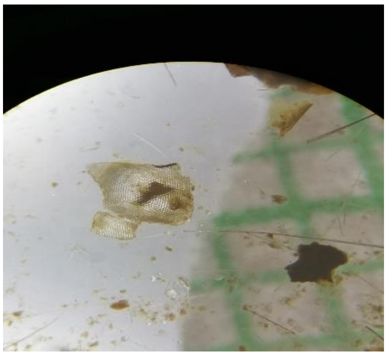


Photograph 17. Coded guano samples for further diet analysis.

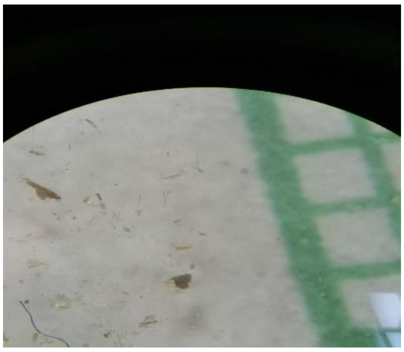
Selected histological photographs of principal prey categories in diet of insectivorous bat of Daunne hill range, central Nepal (1 graph box=1mm) (10X)



Photograph 18. Coleoptera elytra



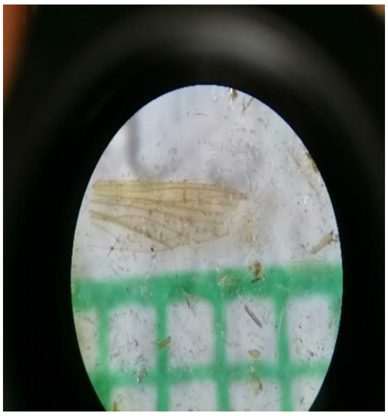
Photograph 19. Coleoptera eye



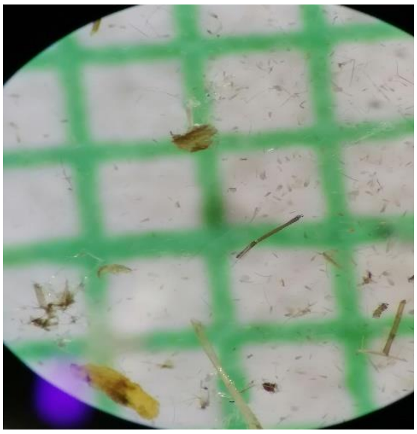
Photograph 20. Lepidoptera scales

Photograph 21. Hemiptera

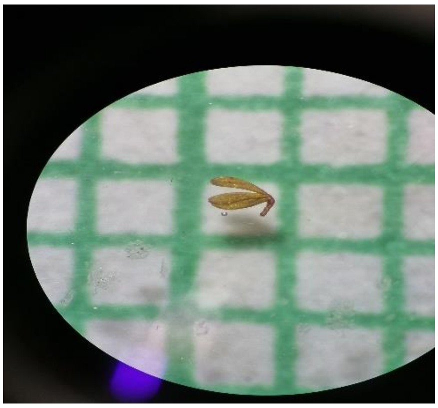
Photograph 22. Diptera wing

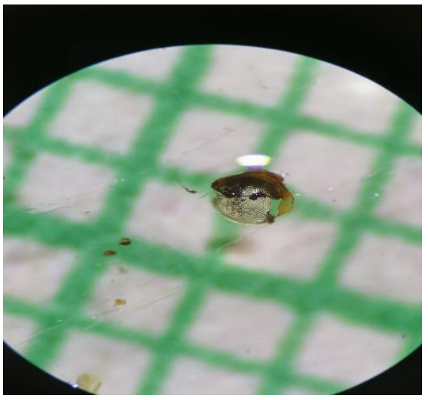


Photograph 23. Diptera wing

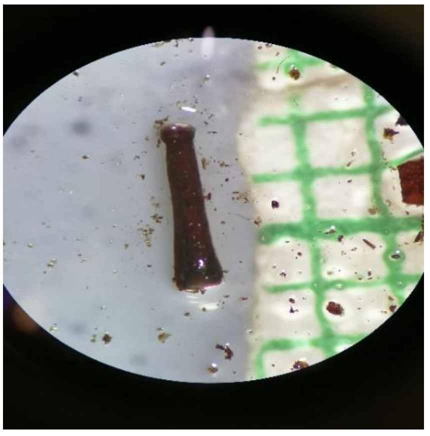

Photograph 24: Diptera leg

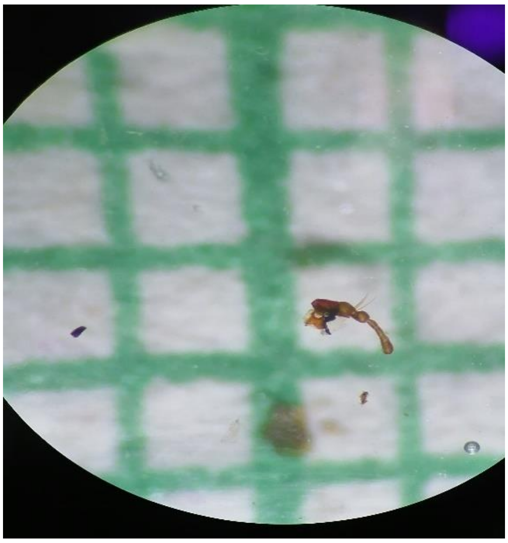

Photograph 25. Hymenoptera wing


Photograph 26. Coleoptera antennae

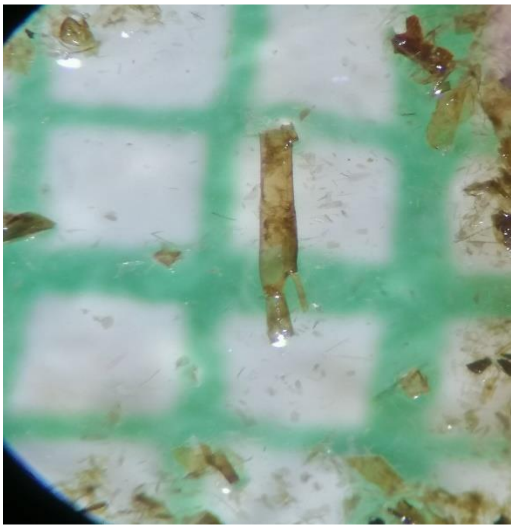

Photograph 27. Coleoptera eye


Photograph 28. Coleoptera maxilla


Photograph 29. Coleoptera leg


Photograph 30. Coleoptera antennae


Photograph 31. Coleoptera wing


Photograph 32. Lepidoptera leg

Appendix II. Permission letter

नेपाल सरकार
वन तथा वातावरण मन्त्रालय
वन तथा भू-संरक्षण विभाग

नेपाल सरकार
वन तथा वातावरण मन्त्रालय
वन तथा भू-संरक्षण विभाग
बबरमहल

फोन नं. ४-२२७५७४, ४-२२०३०३
फ्याक्स: ४-२२७३७४
(कृपया पत्रोत्तरमा प्राप्त पत्र संख्या र मिति उल्लख गर्नुहोला ।
बबरमहल, काठमाडौं, नेपाल

प्राप्त पत्र संख्या र मिति:-
पत्र संख्या:- 06L/65
च. नं.:- १२३५

मिति : २०७८/०९/२०

विषय: अनुसन्धान अनुमति सम्बन्धमा ।

श्री दिक्षा पौडेल
परासी, नेपाल ।

प्रस्तुत विषयमा प्राणी शास्त्र केन्द्रिय विभाग, कीर्तिपुर, काठमाण्डौमा तेश्रो सेमेष्टर Ecology मा अध्ययनरत तपाइले "Species Diversity and Diet Analaysis of Insectivorous Bat in Daunne Hills, Nawalparasai, Central Nepal" को विषयमा फिल्ड अनुसन्धानका लागि अनुमति उपलब्ध गराइदिनु हुन भनि मिति २०७८/०९/१८ गते यस विभागमा दिनु भएको निवेदन साथ प्रपोजल प्राप्त भयो । सो सम्वन्धमा कारवाही हुँदा उक्त प्रपोजलमा उल्लेखित Methodology (Mist netting, Harp trapping, Guano collection) अनुसार तपसिलको शर्तहरुको अधिनमा रही डिभिजन वन कार्यालयसँग समन्वय गरि सन् २०२२ डिसेम्वर सम्मका लागि अनुसन्धान गर्नु हुन निर्देशानुसार अनुरोध छ ।

शर्तहरु

१. अनुसन्धानकर्ताले वन ऐन २०७६ तथा वन नियमावली २०५१, राष्ट्रिय निकुञ्ज तथा वन्यजन्तु संरक्षण ऐन, २०२९ र नियमावली २०३० तथा यस मातहतका नियमावलीहरुको पूर्ण पालना गर्नुपर्नेछ ।
२. अनुसन्धान कार्य डिभिजन वन कार्यालयसँगको समन्वयमा गर्नुपर्नेछ ।
३. नमुना संकलन कार्य डिभिजन वन कार्यालयको प्रत्यक्ष रोहवरमा गर्नु पर्नेछ र संकलित नमुनाहरुको परिक्षण प्राणी शास्त्र केन्द्रिय विभागको प्रयोगशालामा गर्नु पर्नेछ ।
४. अनुसन्धानको कममा प्राप्त भएको जैविक विविधता संरक्षणसँग सम्बन्धित संवेदनशिल सूचनाहरु गोप्य राख्नु पर्नेछ । अनाधिकृत रुपमा त्यस्ता सूचनाहरु कसैलाई पनि उपलब्ध गराउन पाइने छैन ।
५. १ वर्षको अध्ययन अनुसन्धान कार्य समाप्त भए पश्चात एक प्रति प्रतिवेदन (कागजी तथा विद्युतिय) यस विभागमा अनिवार्य रुपमा बुझाउनु पर्नेछ
६. तोकिएका शर्तहरुको पालना नगरिएमा विभागले कुनै पनि समयमा अनुसन्धान अनुमति रद्द गर्न सक्नेछ ।

माधुरी कार्की (थापा)
उप-सचिव(प्रा.)

बोधार्थ
श्री डिभिजन वन कार्यालय, नवलपुर (व.सू.पु), नवलपरासी (व.सू.प) : जानकारी तथा आवश्यक सहयोगका लागि अनुरोध छ ।