ROOST SELECTION AND DIET ANALYSIS OF LESCHENAULT'S ROUSETTE BAT (*Rousettus leschenaultii* Desmarest, 1820) IN BHIMAD AREA TANAHUN, NEPAL

Submitted by:
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Submitted to:
Central Department of Zoology
Institute of Science and Technology
Tribhuvan University
Kirtipur, Kathmandu
January, 2021

DECLARATION

I hereby declare that the work presented in this thesis is original and 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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RECOMMENDATION

This is to recommend that the thesis entitled **"ROOST SELECTION AND DIET ANALYSIS OF LESCHENAULT'S ROUSETTE BAT (*Rousettus leschenaultii* Desmarest, 1820) IN BHIMAD AREA TANAHUN, NEPAL"** has been carried out by Miss. Sangita Thapa for the partial fulfillment of Master's Degree of Science in Zoology with special paper Ecology. This is her original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institutions.

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LETTER OF APPROVAL

On the recommendation of supervisor "Prof. Dr. Tej Bahadur Thapa" this thesis submitted by Miss. Sangita Thapa entitled "**ROOST SELECTION AND DIET ANALYSIS OF LESCHENAULT'S ROUSETTE BAT (*Rousettus leschenaultii* Desmarest, 1820) IN BHIMAD AREA TANAHUN, NEPAL"** is approved for the examination in partial fulfillment of the requirements for Master's Degree of Science in Zoology with special paper Ecology.

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CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Sangita Thapa entitled **"ROOST SELECTION AND DIET ANALYSIS OF LESCHENAULT'S ROUSETTE BAT (*Rousettus leschenaultii* Desmarest, 1820) IN BHIMAD AREA TANAHUN, NEPAL"** has been approved as a partial fulfillment for the requirements of Master's Degree of Science in Zoology with special paper Ecology.

EVALUATION COMMITTEE

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LIST OF ABBREVIATION

Abbreviated form	Details of abbreviation
GPS	Global Positioning System
Sp.	Species
HB	Head Body
T	Tail
HF	Hind Foot
FA	Forearm
2Ph 3mt	Second phalange third metatarsal
E	Ear
Df	Degree of freedom
Ht.	Height
IUCN	International union for conservation of nature
Mm	Millimeter
Km	Kilometer
Gm	Gram
◦c	Degree Celsius

ABSTRACT

Bats are mammals belonging to the order Chiropteran the second largest to the order among 26 mammalian groups. Bats are the only mammals capable of true and sustained flight with their forelimbs adapted as wings. The main objectives of this study were to identify co-habitant bat species with *Rousettus leschenaultii* at the study cave, determine population and evaluate factors influencing roosting refugia, enumerate diets of *Rousettus leschenaultii* at the study area Bhimad, Tanahun Nepal. Possible roosting sites were surveyed and mist netting was used to capture bat and observed directly. Morphometric measurements, taxonomic characters, were used to identify species. High resolution photographs were taken to estimate the population. The height of roost site, distance of roosting sites of bats inside Chamero cave was measured using measuring tape (Pythagoras theorem). The seeds of potential food of fruiting plants, mostly ripe fruits were collected. Plastic sheets of 1-1m size were placed randomly in six different locations inside the cave to collect fecal matters of bats. Total 156 fecal samples were collected from the Chamero cave twice in a month.The correlation between population and height of roost refugia, distance of roost refugia from cave entrance were analyzed using correlation in R-studio. Also, regression analysis was performed to analyze relation between bat population and physical factors. The collected samples of guano were analyzed using collected potential food items. The family wise composition of diet items were analyzed using MS Excel 2010. A total four roosting sites were identified with eight species of bats. The height of roosting refugia and bat population was found to be moderately correlated (r=0.55) whereas, distance of roosting refugia from cave entrance and bat population was found to be in a weak correlation (r=0.44). Among four roosting sites Bhalu cave has the highest diversity of bat species with being longest cave. The bat species were found to be roosting in the highest refugia inside Chamero cave. The distance of roosting refugia from cave entrance don't have any effect on roosting refugia. Thirty three plant species were collected as potential diets from 20 families. A total of 11 species of fruiting plant were identified as diet of *Rousettus*. Among these twenty five percent were found to be cultivated fruits and 75% were found to be wild fruits. This study on the diversity and habitat of bats can help understand the ecological interaction. This can enhance knowledge of locals especially farmers about importance of bats.

INTRODUCTION

1.1 Background

Bats are unique mammals with flight. To fly bats possess wings that is modified forelimbs, much as are bird wings, except in the case of bats the flight surface is covered with skin and supported by four fingers, while in birds the flight surface is provided mostly by feathers and is supported by the wrist and two digits. Bats are the diverse group of mammals which represents the variation on a single basic theme: flying mammals that means no mammals other than bats have true wings and flight. Bats differ from other mammals through the characteristic traits like flight and echolocation (Arita *et al*., 1997).

1.1.1 Taxonomy and distribution of bats

Bats belong to the order chiropteran, the second largest order among the 26 mammalian orders which includes latest record of 1,117 species throughout the World (Srinivasulu *et al*., 2010). In history scientists have divided the order chiropteran into two sub-orders: Mega-chiropteran and Micro-chiropteran each consisting of 186 species of old world fruit bats in one family and 931 species in 17 families respectively (Mickleburg *et al*., 1992; Mickleburg *et al*., 2002; Srinivasulu *et al*., 2010).

Bats are widely distributed and have been recorded throughout the world in tropical and temperate habitats except Antarctic, Polar Regions and some isolated Oceanic Islands (Mickleburg *et al.,* 2002). Bats are very common in temperate regions but their great diversity is found in the tropical forests (Hill and Smith, 1984; Vaughan *et al*., 2000). Some 128 species has been known from South Asia (Srinivasulu *et al.,* 2010). A total 56 species of bats has been reported in Nepal (Thapa, 2018). The reported number of bat species represents about 5% of the world bat diversity and over 40% of the South Asia’s diversity. The fruit bats are bound to the tropical and subtropical regions (Rajchal, 2007) whereas; the majority of insectivorous bats live in the tropics. Fruit bats are mainly found in the tropical, semi-evergreen, and moist deciduous and dry deciduous zones of the Peninsula. The distribution of insectivorous bats are restricted by climate and other factors whereas, the planting of trees by humans has provided a shelter for fruit bats.

1.1.2 Leschenault's rousette (*Rousettus leschenaultii* Desmarest, 1820)

Leschenault's rousette bat (*Rousettus leschenaultii* Desmarest, 1820) is one of the old world bats belonging to the family Pteropodidae. It is also called Saano Badura (Baral and Shah, 2008) and Jibro Padkaune falahari Chamero locally (Acharya and Adhikari, 2010). *Rousettus leschenaultii* is distributed in Nepal, Sri Lanka, Pakistan, Vietnam, Southern China, Peninsular Malaysia, Sumatra, Java, Bali, Indonesia (Simons, 2005). Like other fruit bats, this species is a tropical cave dweller species and are able to exist in a temperate climate as well. *Rousettus leschenaultii* is found in variety of habitats ranging from tropical moist forest to urban environments (Acharya and Adhikari, 2010). This species is medium in size measuring from 12.5cm and tail 2cm with uniformly light brown but occasionally yellowish in color. Older male is grayish in color. Leschenault's rousette sheds and completely becomes hairless during the spring and summer. The young ones of these fulvous bats are pink and naked at birth and carried by the mother for two month during her nocturnal flight. The juveniles after being independent, they live in exclusive colonies of their own. These bats roosts in noisy colonies ranging from 10-2000 and it is found up to 2150m elevation in the Himalayas (Rajchal, 2016). They roost in caves and man-made structures such as tunnels, rocks, caves, wells and rooms in old ruins. These fruit bats have a very good sense of smell so they travel to the far distances to forage (Rajchal, 2016).

1.1.3 Roost selection and diet

Resource selection by animals is an important for the determination of fitness and is a focus of many ecological studies (Franklin *et al.,* 2000) particularly for examining species occurrence and habitat selection (Manly *et al*., 2002). Resources selection models are commonly developed by comparing habitat characteristics at sites that were used by animals to those that were potentially available (Manly *et al*., 2002). Bats have a greater diversity of behavior, diet and morphology than any other mammalian species. Bats shows an impressive diversity of feeding habits including frugivorous, insectivorous, nectar feeders, some feeds on small vertebrates and some feeds on bloods (Arita *et al*., 1997). As the primary predators of nocturnal insects, bats play a significant role in all forested ecosystems (Fenton, 2003). One third of the world's 900 species of bats visits plants to eat nectar, pollen and fruits (Fleming, 1993). They fly and forage the far distances to find food and other resources. As bats have known as the cave dwellers, the limiting factors for them in definitive subterranean life are food resources, insect size and low biomass in cave, low potential prey for carnivores and fruit, nectar for frugivorous. So, bats are epigeous in nature and leaves cave daily to find resources (Trajano, 1995), this behavior is also known as foraging. Most of the plant visiting bats live in the tropics or the subtropics. These plant visiting bats belong to the two families of bats orders: the new world Phyllostomid and the old world Pteropodidae. *Rousettus leschenaultii* bats are phytophagous in diet and they feeds on fruit, flower, nectar, and pollen, parts of the leaves (Acharya and Adhikari, 2010) to fulfill their energy need.

Rousettus leschenaultii generally roosts in natural roosting sites like cavities of caves and also roosts in manmade structures like old and ruined buildings, forts and disused tunnels in colonies ranging from a few to several thousands (Acharya and Adhikari, 2010). The roost of this species is usually quite noisy. Most of the Phyllostomid bats roosts relatively close to their nocturnal feeding areas (Fleming, 1993) which may be to avoid predators, to maximize the food and energy intake and to minimize the energy loss during their foraging activity.

1.2 Statement of problems

Bats are important components of biodiversity but even after being the important element for biodiversity they are often depreciated in conservation and management plan which is due to the lack of information on population status and habitat requirements (Pierson, 1998; Richards and Hall, 1998). Many bats are threatened due to major problems like lack of awareness, habitat loss, poaching and trapping, caves turned into attractions. They have also been disturbed by farmers collecting their excrement, excessive use of insecticides. So, the study on roost site selection will be helpful for the management and conservation of *Rousettus leschenaultii*. Bats plays as keystone species in biodiversity by limiting their prey populations where they are most abundant. *R. leschenaultii* are categorized as common species in Nepal. Even they are reported facing hunting pressure on flowering and fruiting patches of butter trees (*Diploknema butyraeceae*). We are yet to know actual food resources consumed by them at particular locality. Hence, in this study, the prime focus is to identify local food resources around the study cave locality. Moreover, the cave used by them as roost resource can be additional information. The bat community sharing the cave will be additional information.

1.3 Objectives

1.3.1 General objectives

- To explore bat diversity in the study area, evaluate roost site selection and diet of *Rousettus leschenaultii*.

1.3.2 Specific objectives

- To identify co-habitant bat species with *Rousettus leschenaultii* at the study cave.
- To determine population and evaluate factors influencing roosting refugia.
- To enumerate diets of *Rousettus leschenaultii* at the study area.

1.4 Research questions

1.4.1 Determine the species diversity and status of bats in Bhimad area, Tanahun Nepal?

1.4.2 Does physical factors such as height of roosting refugia and distance of roosting refugia to the cave entrance affects roosting refugia selection bybats?

1.4.3 What are the potential diets of frugivorous bat *Rousettus leschenaultii?*

LITERATURE REVIEW

While reviewing the bats in context of Nepal, fifty over species are reported in various sources (Acharya *et al*. 2010). In Nepal, mammalian documentation for scientific purpose was formerly initiated by the British Ambassador Brian Hudson, who recorded the number of faunas including bats. Nepal is a rich country in Chiropteran diversity occurring 45 percent species of bats found in South Asia and 4.6 percent of the world (Huston *et al*., 2001). Later on other foreign expedition team updated the database time to time. Scully (1886) published one of the earliest reviews of bats of Nepal. In the 1950s and onward many foreigners from North America and Germany were attracted to Nepal because of the incredible geographic, botanical and zoological diversity of Nepal. This leads to more exploration and findings in biodiversity of Nepal. The major contributors to the study of bats in Nepal were Hodgson (1834, 1835), Abe (1982) , Hinton and Fry (1923), Sanborn (1950), Sinha (1973), Johnson *et al.* (1980), Mitchell (1980), Abe (1982), Kock (1996), Bates and Harrison (1996). Hodgson (1996) collected 373 mammal species, belonging to 7 genera and 114 species, was the first collector who described the fauna in this country. Abe (1982) has recorded about 570 terrestrial small mammals, consisting of 28 species from central Nepal and contributed in identification of several bat species (Phuyal, 2005). Abe (1982) reported on bats of Central Nepal, including eight species in three families. Which includes: *Cynopterus sphinx* (Pteropodidae), *Rhinolophus affinis himalayanus*, *R. rouxirouxi*, *R. pearsoni* (Rhinolophidae), *Myotis mystacinus muricola* (*M. muricola*), *Myotis siligorenissiligorensis*, *Pipistrellus babu* (*P. javanicus*), *and Miniopterus Schreibersii fuliginosa.* Later three species of namely *Ia io, Murina cyclotis and Kerivoula hardwickii* recorded for the first time from Nepal with new checklist of 51 species known from Nepal (Csorba *et al*., 1999).

From 2000 Nepalese started to study on bats (Adhikari, 2007). Acharya (2006) worked and studied on the distribution, roosting and survival threats of bats in Pokhara valley with the distribution of roosting and survival threats of bat in Pokhara valley reference to species and population survey at Bat Cave, Pokhara and found that the cave is roosting site for more than 3,000 (13.75 per sq. m at winter and 0.21 per sq. m at summer). They identified two bat species viz. *Rhinolophus pusillus* and *Hipposideros armiger* in the cave. Phuyal (2005) surveyed bats of Pokhara valley and documented a total of twelve bat roosting sites and eleven species.The study on the behavior on flying fox bat was done for the first time in Sallaghari, Bhaktapur (Koju, 2008). Many other surveys have been done in which colonies of flying fox was found in eastern Terai of Nepal (Thapa, 2008 and Thapa, 2009). Monitoring on bats was also done by Thapa *et al*., 2009; Thapa and Thapa, 2009; Giri, 2009; Thapa *et al*., 2010; Ghimire *et al*., 2010. The frequency of bat studies in various dimensions such as distribution, ecology, health, taxonomy and conservation has been increasing in last decade. First legal paper Biodiversity Profile Project was published in 1995 in which 37 bat species was considered to occur in Nepal (Suwal *et al*., 1995). According to South Asian Chiroptera Conservation Assessment and Management Plan (C.A.M.P.) Workshop Report, 2002 Nepal consists of 51 species of bats which are as follows: 5 data deficient, 5 Vulnerable, 20 Not-threatened, and 17 Least concerned, 2 Critically Endangered, 1 Endangered, 1 Status unknown. But few other researchers compile few more bats in Nepal.

Some extensive research on bats has been carried out in some parts of Southeast Asia (Francis *et al.*, 1996, Robinson and Webber, 1998) but in other parts of this region there is a shortage of even basic information about bats specially the roosting site selection of cave bats. While reviewing the literature for resource selection on bats roost selection and food selection are two major discussed aspects. Bats are either solitary, group living or colonial. Colonial bats either lives in cave roosts (such as *R. leschenaultii, Eonycteris spelaea)* or in tree roosts (such as *Pteropus giganteus*). It is assumed that bats live in colony serves to conserve heat which is vital because they have high metabolic rate despite being small in size. Roost sites provide bats the site for mating, hibernation, rearing young ones, protection from adverse weather and predators also the roosting conditions are the main factors to balance natality, mortality and survivorship of these bats (Kunz, 1982).

Kunz (1982) and Tuttle and Stevenson, (1982) studied about the implications of roost site selection on the life history of bats like these can be vital for their survival. They also studied for many temperate bats; these can be separated into winter hibernacula, maternity roosts and summer roosts for males and non-reproductive females. In addition, many bats use specific night roosts in close proximity to foraging areas which may function as resting places that facilitate digestion between feeding bouts and may provide opportunities for social interactions (Kunz, 1982). Thus, it is important to understand the roosting requirements of bats to ensure adequate roost protection and availability.

Hill and Smith (1984) and Vaughan *et al*., (2000) studied many bats hibernate during winter and undergo daily torpor to conserve energy while roosting together can further reduce heat loss. According to their study many bats roosts together in groups from thousands to millions while they defend their foraging area in groups and roosting sites as well. There is not much study about the roosting selection and roosting preferences by the bats in Nepal. Alcock (1989) studied some behaviors of bats such as dispersal, migration, and movement between alternate dens or roosts which are of interest because they potentially involve costs related with leaving a familiar area which may increase risk of predation, lower familiarity with foraging opportunities, disrupt social bonds, cause loss of energy invested in construction of prior roosts or dens, and increase energy output to search for a new place to live.

As claimed by Churchill (1991) species that cannot enter torpor will select those roosts microclimates which approximate their thermo neutral zone. Also, the degree of dependence on caves for their activities and preference on some type of roosts was studied by Trajano (1995). Bats roosts in cool conditions to lower their resting metabolic rate during this period of limiting food sources (Nagel and Nagel, 1991; Web *et al.,* 1996). As stated by Churchill *et al.,* (1997) in winter many bats roosts in cool conditions to reduce their body temperature and enter into hibernation. In general, protection of only one roost type is not adequate and temporal variation, roost selection must be accounted for determining conservation goals (Fenton, 1997; Pierson, 1998). It was later studied by Tuttle and Stevenson (1997) and according to them structural and elevation complexity and increased cave size generally will contribute to this desired thermal range for bats.

Twente (1955) noted that heat is absolutely necessary for bats to choose roosts with temperatures appropriate to the desired metabolic processes like warm for digestion and growth in the summer, and cool for torpor in the fall and winter, with the exact optimum temperatures varying somewhat among species.While the cave microclimates varies with distance from the cave entrance, height above the floor, depth below the surface, distance from the water table, presence of pools of water, amount of air movement, size and shape of cave passage or chambers and presence of other bats (Twente, 1955; Dwyer and Harris, 1972; Churchill, 1991). Dwyer and Hamilton (1965) and Bernard and Bester (1988) stated some bats need a range of different microclimates during the year to suit their changing needs.

Many studies done by scientists has shown that many factors such as number, size, and position of entrances, passage size, contour and slope, overall cave volume, distance of greatest volume from entrances, amount and seasonal timing of entry of surface water, air flow, and the annual range of outside temperature strongly influence cave temperature and humidity (Halliday, 1954; Moore and Nicholas, 1964; Plummer, 1964; Cropley, 1965; Geiger, 1965; Peters, 1965; Vandel, 1965; Conn, 1966; Barr, 1968; Daan and Wichers, 1968). Various studies show that variation in temperature and humidity inside cave has great impact on cave faunas (Jegla and Poulson, 1969; Juberthie and Delay, 1973; Delay, 1974; Juberthie, 1975; Poulson, 1975; Tuttle, 1975; Wilson, 1975; 1976; Peck, 1976).

According to Racey (1969) and Dwyer and Harris (1972) the ideal cave environment for bat is one which offers a large thermal range which provides ability to move among temperature zones. In a study by Harmata (1973) for cave dwelling bat species, the selection of appropriate roosting temperatures is very important. Selection of suitable roosts is important for growth, development and survival of young (Tuttle, 1975; Tuttle and Stevenson, 1982), protection from predators (Fenton, 1983), protection from the elements (Vaughan, 1987), and reduction of thermo regulatory costs (Kurta, 1985). Roosting sites of bats are important for them which were emphasized by Bradbury (Kunz, 1982).

In fruit bats, food availability in the surrounding environment is another issue. Mega chiropterans eat mainly on fruits, nectar, young shoots or leaves. Many studies on the diet analysis of insectivorous bats like Malla (2000) studied the diet analysis of *Hipposideros armiger* and *Rhinolophus pusillus* (Micro Chiroptera) of Nagarjun Cave using stomach content analysis to find out the food items have been done using different methods but still the diet analysis of fruit bat *Rousettus* is still untouched in Nepal. As stated by Tuttle (1997) more than 300 plant species in the Old World tropics depends on the pollinating and seed dispersal services of bats and additional bat-plant relationships are constantly being discovered, in this we human beings and other organisms are benefited by this because these plants provide more than 450 economically important products, valued in the hundreds of millions of dollars annually, not only the wild species of plants but also many economically valuable crop plants also rely on bats for survival but also commercially growing fruits such as bananas, bread fruit, avocados, dates, figs, peaches, and mangoes. Worldwide, bats play an important role in keeping populations of insects in balance, helping in pollination and seed dispersion, by which they act as the friend of farmers.

Giannini (1999) noted that the seasonal variations in diet are thought to lead to altitudinal movements of bats. Study done by Korine *et al.*, (1999) the diet of the fruit bats, in caves consisted only of plants in the form of fruits, leaves and pollen with no evidence of insect remains found in the droppings. They feed on almost every kind of cultivated fruit, and upon the flowers of such trees as the mango and the cashew nut. *Rousettus* always favored the ripe fruits and they ignores the raw ones (Korine *et al.,* 1999, Hutson *et al.,* 2001). Kunz and Fenton (2005) also found, those plant species which depends on vertebrates for pollination and dispersal of their seeds favors a large number of plant visiting bats. Food habit of insectivorous bats was studied using fecal analysis by Pokhrel and Budha in 2014.

The field observations did by Vanlalnghaka (2015) in the Lengteng sanctuary show that the fibrous ripe fruits like figs, willughbeia, guava etc. from the orchards in the sanctuary were selected by *R. leschenaultia* by sniffing. They feed on almost every kind of cultivated fruit, and upon the flowers of such trees as the mango and the cashew nut. These bats extracted the juice of fruits by chewing them for 3-6 min. They show a definite preference for the perennial fruit resources to such an extent that they eventually become selective feeders. As specified by Vanlalnghaka (2015), the frugivorous bats, *Rousettus aegyptiacus* preferred to consume a large quantity of figs and each bat consumed about ten figs per night. They also evaluated the seasonal variation in the diet of *Rousettus leschenaultii* from the Lengteng Wildlife Sanctuary ecosystems for one complete year. They identified the plant parts like fruits, flowers, leaves included in the diet of the frugivorous bats by four methods: the field observation on feeding habits, collection of the discarded plant parts from the roosts, analysis of pollens attached to body of the bats and the analysis of fecal matter.

MATERIALS AND METHODS

3.1 Study area

This study was conducted in the Bhimad Kastic environment of Mohariya village located at an altitude of 494 m above sea level with 84.085E latitude and 28.00N longitude. Bhimad is located 5 km south-west from Khairenitar. This site was selected for the study because the scientific study on bats of this region has never been done. It hosts three unique caves within the same forest area: Siddha, Chamero and Bhalu cave. Chamero cave is situated at the uppermost part of the forest area whereas Siddha cave lies beneath it. Chamero cave was further estranged into flanks, right section of cave host a suitable habitat for insectivorous and carnivorous bats whereas, left section congregate more than 1,000 individuals of fruit bats whereas, Siddha cave host a habitat for only insectivorous bats. Bhalu cave was found to be the longest among four caves with length of 200 m. Chamero and Bhalu cave lies at the same height with entrance facing each other. Chamero cave has the highest and widest entrance among them with the entrance height of ten meter and entrance width of nine meter. Chamero cave, Bhalu cave and Sidha cave 2 holds a water source inside. Sidha cave 1 lies 166m away from Chamero cave and Bhalu cave. This area has been recently established as a major tourist attraction of the Municipality. Many constructions on the site have been going on to facilitate the tourists. The bat and cave survey was also carried out on the other side in Bhabar, Syaulibazar. This area is located at an altitude of 492 m above sea level between 84.07716E latitude to 28.00961N longitudes. This area is only 2 km South-West to the Khairenitar. All of the caves lie on the west of the Seti River. Seti River flows through Bhimad providing riverine forest along the river.

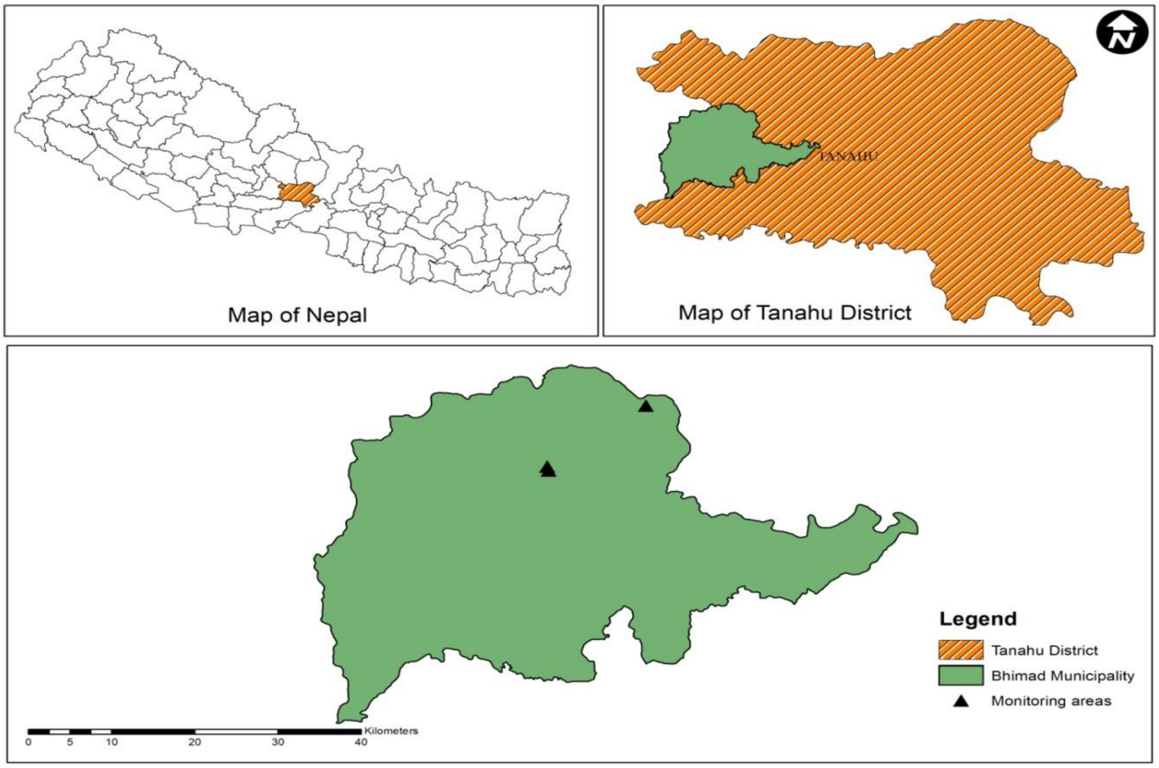

Fig 1: Map of study area

3.2 Climatic condition

This study area lies in the sub-tropical life zone with prevailing Monsoon rains. This region has annual temperature ranging from 15◦c to 45◦c and an annual rainfall up to 2394 mm.

3.3 Flora and Fauna

This region is a meeting ground for both temperate and sub-tropical species, and provides either a home or temporary shelter for a greater variety of species. This area is rich in floral diversity with a deciduous forest. It includes a thick vegetation of Sal (*Shorea robusta*) dominated followed by Butter tree (*Diploknema butyraeceae*), chinquapin (*Castanopsis indica*), Needlewood tree (*Schima wallichi*), Indian laurel (*Terminalia alata*), Small flowered crape myrtle (*Lagerstroemia parviflora*), Cotton tree (*Bombax ceiba*), Red kamala tree (*Mallotus philippensis*), Weeping fig (*Ficus benjamina*), Kadam (*Anthocephalus chinensis*), Indian ash tree (*Lannea coromandelica*) and many other shrubs, herbs are found here.

This area is also rich in faunal diversity. It includes mammals like Rhesus monkey (*Macaca mulata*), Hanuman langur (*Presbytis entellus*), Common leopard (*Panther pardus*) and small mammals like Common mongoose (*Herpestes edwardsi*), Leopard cat (*Felis benghalensis*), Leschenault's rousette (*Rousettus leschenaultii*), Intermediate horseshoe bat (*Rhinolophus affinis*), Big eared horseshoe bat (*Rhinolophus macrotis*), False vampire bat (*Megaderma lyra*), etc. Many bird species like Egyptian vulture (*Neophron percnopterus*), Black drongo (*Dicrurus macrocercus*), Ashy drongo (*Dicrurus leucophaeus*), White throated kingfisher (*Halcyon smyrnensis*), Oriental turtle dove (*Streptopelia orientalis*), Great barbet (*Psilopogon virens*), Black kite (*Milvus migrans*), and Verditer flycatcher (*Eumyias thalassinus*) were observed here. Also, amphibians like Bull frog (*Rana tigrina*), reptiles including Pit viper (*Crotalus horridus*), Oriental garden lizard (*Calotes versicolor*) were also observed. Fish species like Buhari (*Wallago attu*), Gadaula (*Schistura beavani*), Bhoti (*Channa orientalis*), Buduna (*Garra gotyla gotyla*), Rohu (*Labeo caeruleus*), Bam (*Monopterus cuchia*) were also observed.

3.4 Data collection

3.4.1 Preliminary survey

Preliminary survey was carried out from April to July 2017 to identify bat species and roosting sites as well as to identify potential factors affecting roosting site selection by the bats in different caves of Bhimad. The vegetation, water, potential food sources and other resources was also observed.

3.4.2 Roost survey and bat capture

Bats survey was carried out on the Kastic environment of Mohriya Bhimad with different caves of potential roosting sites of bats. The bats were captured using mist nets at the entrance of the Chamero and Bhalu caves. Captured bats were handled carefully, sexed, weighed and measured morphometric characters. The measurements of forearm, head body, thumb, tibia, hind foot, tail, ear, muzzle, phalanges were done using venire caliper. Also, the body weight was taken using spring balance and photographs were taken with the help of cannon camera. Captured individuals were identified to species using morphometric measurements and photographs (Acharya and Adhikari, 2010) with the morphological characteristics.

3.4.3 Roosting refugia selection

Bats were surveyed in four different caves of Bhimad. Different roosting refugia occupied by bats were identified. The high resolution photographs were taken to estimate the population of bats. Then, grids were drawn on the photographs and populations of bats were counted in each grid. For the data collection the cave was linearly divided into five left and right blocks. Total of seven blocks or cavities were randomly selected to assess the factors such as height and distance to the entrance. These measurements like height (Pythagoras theorem) and distance of the refugia from the entrance of the cave was taken using (50 m) measuring tape. Physical factors like width of the entrance, presence of exit, length of the cave, roosting condition, refugia type, direction of entrance faced, distance of cave to water source, cultivation land, human settlement, road etc. were recorded in all roosting sites along with temperature and humidity inside caves were measured using hygrometer while the height of the entrances of different cave was taken with the help of measuring tape.

3.4.4 Diet

3.4.4.1 Reference food item collection

The reference of local seeds of fruiting plants, mostly ripe fruits collected during November to September 2018. *Rousettus leschenaultii* can fly up to 5-10 km for foraging activities so we collected the reference food items up to 5 km radius from the cave. The seeds were extracted from the fruit and dried. Seeds of trees, shrubs, herbs were collected, classified and leveled separately in a container.

3.4.4.2 Droppings collection

Plastic sheets of 1×1 m^2 size were placed randomly in six different locations inside the cave. Total 156 samples were collected from the site twice in a month (after 15 days of gap) from November 2017 to November 2018. The fecal samples were collected in a tight container with 70% ethanol which was later brought to the laboratory of Central Department of Zoology. The fecal samples were kept in a Petri dish containing hot water and few drops of glycerol to avoid evaporation of water vapors and to soften the samples (Kunz, 1988). Then, the droppings were broken into fine pieces with the help of dissecting needle. The visible seeds were then extracted and separately placed into a Petri dish. The small seeds were then separated with the help of stereo binocular microscope. The collected seeds were compared with the prepared index of known fruits and identified. Those seeds which were difficult to identify were identified with the help of local people.

3.4.4.3 Identification of potential food plants

After the emergence of *Rousettus* from cave they were followed to their potential food plants. The feeding activities of bats were observed using dim light and binoculars. During this observation various feeding activities like landing on the fruit, hovering near the orchard, sniffing the ripe fruits, etc. were observed. The collected 156 samples were diluted in water. Then the undigested seeds were extracted from guano. The seeds were then compared with the collected reference seeds with the help of microscope. This way the potential feeding plants were identified.

3.4.4.4 Timing of bat emergence and return in relation with sunset and sunrise

The time of sunset, emergence, sunrise and return of bats to the cave were recorded. Each of the observations started about 30 minute before the expected onset of emergence and return according to the time of sunset and sunrise. The time of sunset and sunrise were recorded with the help of wrist watch. The emergence and return was observed on the bats of Chamero cave waiting outside the entrance of the cave about 50 m away from the entrance. The observation was continued till the last bat returned or emerged from the entrance of cave. Also, different activities of bats during the emergence and return were observed and recorded.

3.5 Data analysis

The primary data were managed in Excel software and later transferred to R-statistics software for further analysis. Pearson's correlation and regression was performed to analyze the data. For data analysis MS Excel and vegan package in R were used whereas, Arc GIS was used to create a study area map

3.5.1 Roosting refugia selection

The relationships between bat population of roosting refugia and physical parameters like height and distance of roosting refugia were analyzed using correlation in R studio. Also regression analysis was done in R-studio to see the relation between bat population and different parameters of four caves.

3.5.2 Diet

The collected samples of potential food items were managed in Excel 2010. The collected potential food items were analyzed to find the family wise composition. The diet of

Rousettus was also managed and analyzed using Excel 2010. Then, the preferences on wild and cultivated fruits and family wise composition of diet items were analyzed using MS Excel 2010 to find the abundance family of diet.

3.5.3 Timing of bat emergence and return in relation with sunset and sunrise

The data of timing of emergence and return in accordance with sunset and sunrise were assigned in MS Excel file separately as different variables. The time of sunset and sunrise was drawn against timing of emergence and return respectively; in MS Excel. Then the relations between time of sunset and sunrise with bat emergence and return were analyzed.

RESULTS

4.1 Co-roosting / Co-habitant bats

A total four roosting sites were identified in Bhimad area. Eight species of bats including one frugivorous, six insectivorous and one carnivorous bats belonging to six families were recorded. Chamero cave was the main roosting site of *Rousettus* (Table 1).

Table 1– Bat species recorded in Bhimad area and their roosting sites

S.N.	Roosting sites	Common name	Scientific name	Family
1.	Chamero cave	Leschenault's rousette	*Rousettus leschenaultii*	Pteropodidae
2.	Siddha cave 1	Intermediate horse shoe bat	*Rhinolophus affinis*	Rhinolophidae
3.	Bhalu cave	Least horse shoe bat	*Rhinolophus pusillus*	Rhinolophidae
		Great Himalayan leaf nosed bat	*Hipposideros armiger*	Hipposideridae
		Greater false vampire bat	*Megaderma lyra*	Megadermatidae
		Schreiber's long fingered bat	*Miniopterus schreibersii*	Miniopteridae
4.	Siddha cave 2	Big eared horse shoe bat	*Rhinolophus macrotis*	Rhinolophidae
		Lesser mouse eared Myotis	*Myotis blythi*	Vespertilionidae

Among the four caves, Bhalu cave supports higher diversity of bat species followed by Siddha cave 2, while two other cave occupied by one species in each. Two species viz Intermediate horse shoe bat and big eared horse shoe bat were recorded from two different caves (Table 2).

Table 2-Bat occurrence and cave characteristics

S.N.	Roosting sites	No. of bat species	DR (m)	DW (m)	DH (m)	DC (m)	HE (m)	WE (m)	CL (m)
1.	Sidha cave 1	1	614	366	510	374	1.31	1.28	31.69
2.	Sidha cave 2	2	216	236	257	55	2.1	1.8	22
3.	Chamero cave	1	448	200	344	208	10	9.14	34
4.	Bhalu cave	4	448	200	344	208	1.12	6.4	220

Abbreviations: DR= Distance of cave to Road, DW= Distance of cave to water source, DH= Distance of cave to Human settlement, DC= Distance of cave to Cultivation, HE= Height of entrance of cave, WE= Width of entrance of cave, CL= Total cave length.

The occupancy and diversity of bat species in the caves were found to be affected by physical factors. Bhalu cave has the highest diversity among four sites. Bhalu cave is the longest cave which can be the main factor for higher diversity of bats (Table 2).

4.2 Roost refugia and number of individuals

A total seven roosting refugia of *Rousettus* were identified inside Chamero cave. The highest population of *Rousettus* was found inside third roosting refugia. The lowest population of *Rousettus* was found inside first roosting refugia (Table 3).

Table 3 - Bat population of identified roosting refugia inside Chamero cave

S.N.	Roosting refugia	Population	Height of roost refugia (m)	Distance of roost refugia to entrance (m)
1.	R_1	76	4.50	16.6
2.	R_2	97	6.93	21.2
3.	R_3	211	12.86	27
4.	R_4	107	8.33	39
5.	R_5	126	8.57	21
6.	R_6	96	5.95	26
7.	R_7	183	11.29	38.9

Abbreviations: R_1= first roosting refugia, R_2= second roosting refugia, R_3= third roosting refugia, R_4= fourth roosting refugia, R_5= fifth roosting refugia, R_6= sixth roosting refugia, R_7= seventh roosting refugia.

The results on influence of height and distance of roosting refugia on bat population inside Chamero cave showed there were no strong relationships between them **(**appendix 3). The correlation between height of roost cavity and bat population was found to be moderately (r=0.55) correlated. While the correlation between bat population and distance of roost from cave entrance was found to be a weak (r=0.44) correlation (appendix 3).

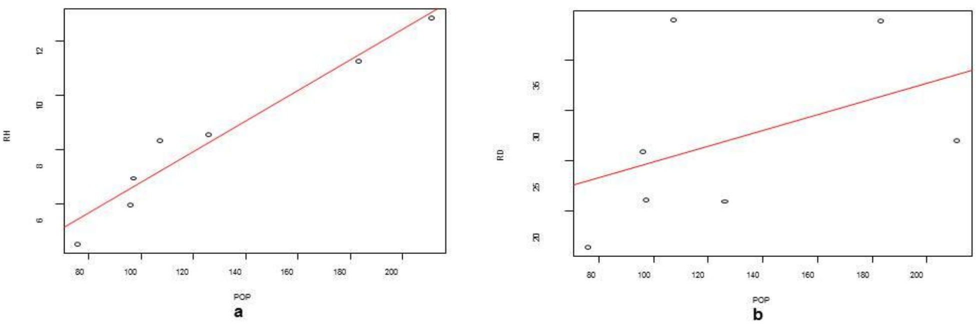

Fig 2: Regression line between bat populations with (a) Roosting refugia Height, (b) Distance of Roosting refugia from cave entrance.

The regression line (a) shows positive relationship between roost height and bat population. Similarly, the regression lines of (b) shows bat population and distance of roost refugia from cave entrance are not strongly related.

4.3Diets of *Rousettus leschenaultii*

A total of 11 fruiting plant species were identified in the fecal matter of *Rousettus*. Twenty five percent were found to be cultivated fruits and 75% were found to be wild fruits. The seeds of the wild fruits were mostly found on the collected fecal matter of *Rousettus* (Table 4).

Table 4-Diets (fruits) of *Rousettus* in Bhimad area

S.N.	Family	Scientific name of plants	Common name of Plants	Category
1	Moraceae	*Ficus glaberrima*	Pakhuri	Wild
2	Bombacaceae	*Bombax ceiba*	Silk cotton tree	Wild
3	Sapotaceae	*Aesandrabutyracea*	Nepal butter fruit	Wild
4	Polygonaceae	*Aconogonummolle*	Vegetable smart weed	Wild
5	Rubiaceae	*Anthocephalus chinensis*	Kadam	Wild
6	Moraceae	*Ficus benjamina*	Golden fig	Wild
7	Moraceae	*Ficus benghalensis*	Banyan tree	Wild
8	Caricaceae	*Carica papaya*	Papaya	Cultivated
9	Myrtaceae	*Psidiumguajava*	Guava	Cultivated
10	Musaceae	*Musa paradisiaca*	Banana	Cultivated
11	Rutaceae	*Citrus reticulata*	Mandarin orange	Cultivated

A total of 33 plant species belonging to 20 families were collected as potential food of *Rousettus.* Among them most abundant family was found to be from Moraceae family (Fig 3).

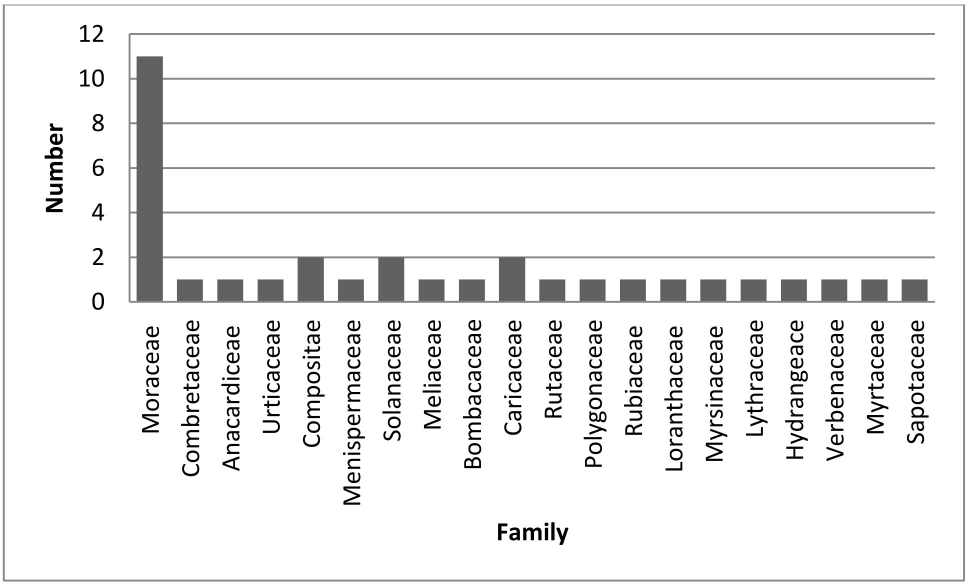

Fig 3: Family wise composition of potential diets

The pie chart (Fig 4) showed *Rousettus leschenaultii* mainly feeds on plant species from Moraceae family. The 28% diet of *Rousettus* comes from Moraceae family.

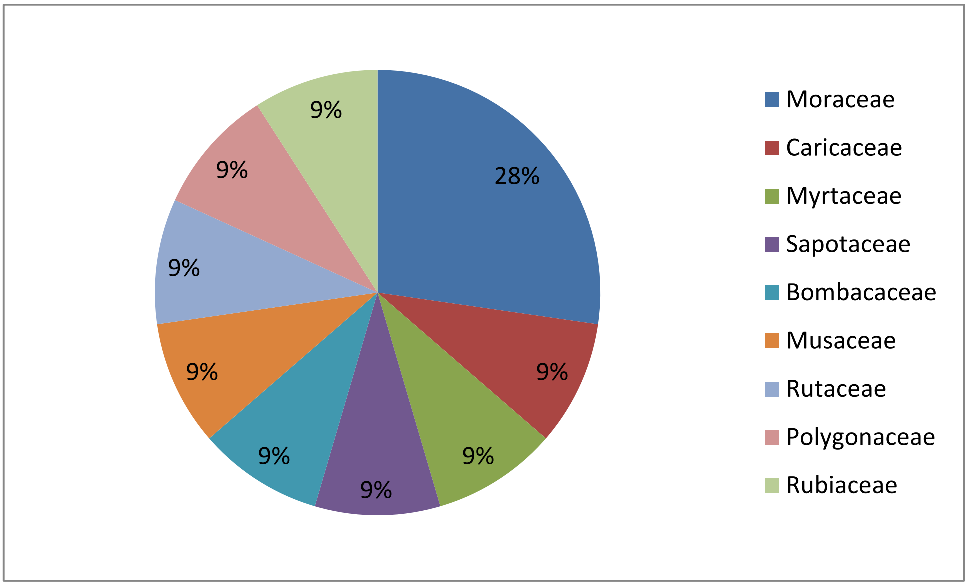

Fig 4: Family wise composition of diet of *Rousettus*

4.4Timing of bat emergence and return in relation with sunset and sunrise

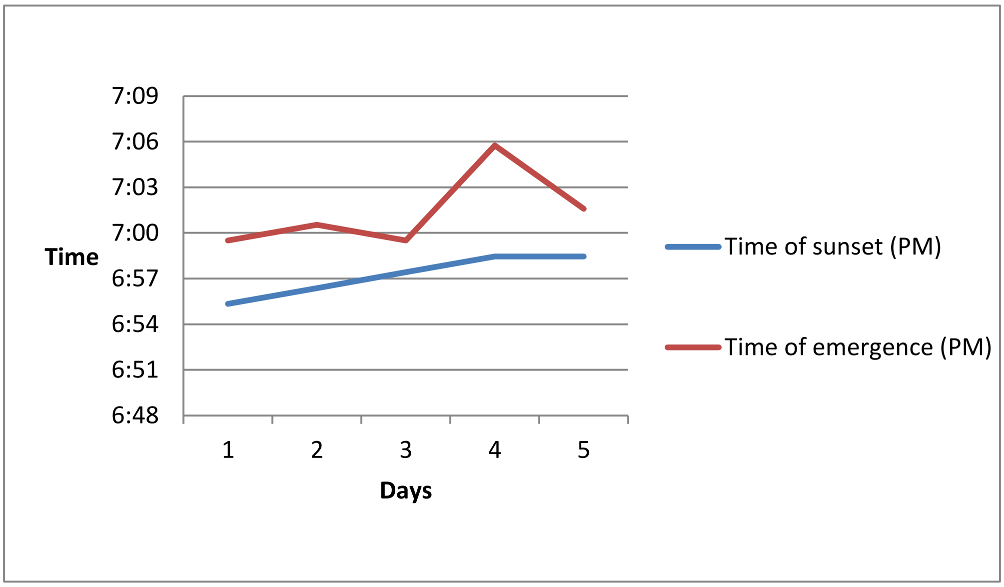

Fig 5: Times of sunset and bat emergence

The time of emergence gradually increased and decreased according to the time of sunset. The gradual increase and decrease in between time of sunset and time emergence showed the positive relation. This result showed that bats emerge out of the cave just 2-4 minute in average after sunset. However in fourth day there was delay in the emergence which was due to the raining (Fig 5).

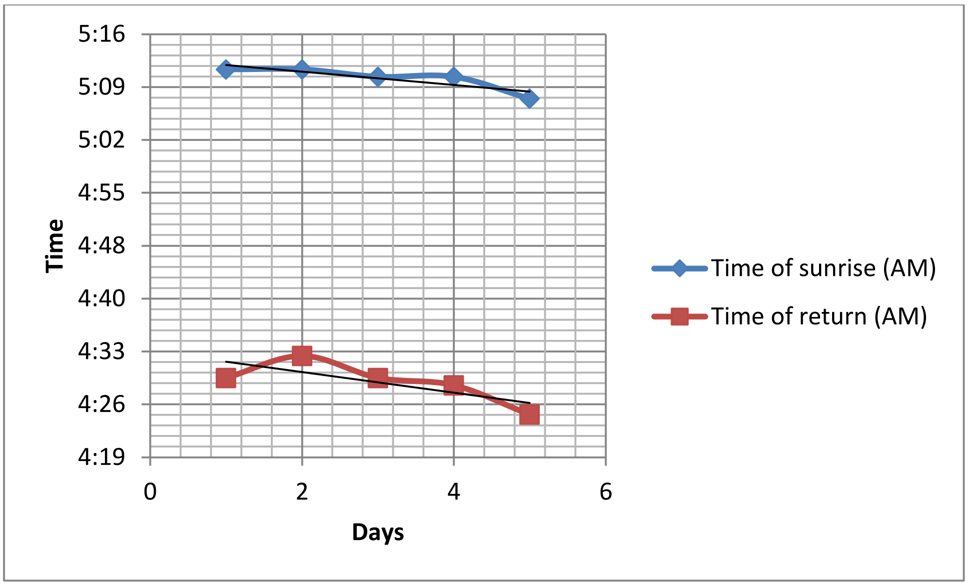

Fig 6: Times of sunrise and bat return to the roosting sites.

It was found that some individuals return to the cave while some took flight straight to the south part of the forest. The process of entering was also rapid usually making more than one approach while some hovered in front of the entrance. During this process in each approach speed of flight was reduced and on final approach it entered directly without a visible break in flight. The time of return gradually increased and decreased according to the time of sunrise. The linear line of graph shows a positive relation between time of sunrise and time of return of bats. This result showed that bats returns to the cave just 30-40 minute in average before the sunrise (Fig 6).

DISCUSSION

5.1 Bat diversity

This study identifies four roosting sites in Bhimad area. Altogether, eight species of bats, namely *Rousettus leschenaultii*, *Rhinolophus affinis*, *Rhinolophus pusillus*, *Hipposideros armiger*, *Megaderma lyra*, *Miniopterus schreibersii*, *Rhinolophus macrotis*, *Myotis blythi* were confirmed during the study period. Among the caves, Bhalu cave recorded more species of bats. This indicates the conservation priority to the cave. The bats in the caves include only one frugivorous i.e. *Rousettus leschenaultii*.

Rousettus is smaller in size than Pteropus with head body ranging from 111-147 mm. Pelage of *Rousettus* is soft, fine and silky with darker tone. It has fulvous brown color on the head, back, flanks, throat while more grayish on the belly. Other species are insectivorous and one species is carnivorous bat i.e. *Megaderma lyra*. *Rhinolophus affinis* is one of the insectivorous bats with short pinnae which arise to the highest level of head. It has head body range from 46-68 mm. It has brown to distinctive orange color while female appears to be darker in color. *Rhinolophus pusillus* is the small sized among Rhinolophidae bat. It has head body range from 30-40 mm. It has buffy brown on the dorsal side with paler color in the ventral with white tinges. *Rhinolophus macrotis* is commonly called Big-eared horseshoe bat. It has head body range from 39-48.7mm. The dorsal pelage is buffy brown with slightly paler in the ventral side. The identifying character of this bat is pinna which is characteristically large.

Hipposideros armiger is the largest hipposiderid bat. It has four supplementary leaflets with the outer leaf distinctly smaller than the other three as an identifying character. It is dark grey brown on the head and shoulders while ventral surface is paler in color. It has head body ranging from 82- 105 mm. *Miniopterus schreibersii* has highly developed second phalanx of the third digit in each wing. It has head body ranging from 47-65.6 mm. The dorsal pelage is blackish brown in color with slightly paler in the ventral side. *Megaderma lyra* has a characteristic features like oval and large shaped pinnae. Forehead and upper cheeks of face is hairy. It has head body ranging from 70-95 mm. The dorsal pelage is mouse gray and ventral pelage is whitish in color. *Myotis blythi* is also called lesser mouse-eared bat. It has head body ranging from 65-80 mm. *Myotis blythi* has large pinnae among genus Myotis. It has buffy brown color in the dorsal with dark grey at roots while paler on the ventral side with dark hair roots.

Among the recorded bat species seven were listed as least concern and *Miniopterus schreibersii* was listed as near threatened by IUCN. Also, in national level six species were listed under least concern and two were listed as data deficient.

5.2 Roost refugia selection

The bat diversity and their population was found to be affected by factors distance to road, distance to water sources, distance to human settlement and cave length. Bhalu cave was found to be the longest cave among four with highest diversity of bats. There are many extrinsic factors that also affect diversity of bats air temperature (Kunz 1973; Lacki 1984; Negraeff and Brigham 1995; Hayes 1997), rainfall (Fenton *et al.*, 1977, Parsons *et al.,* 2003), relative humidity (Lacki1984; Adam *et al.,* 1994).

Inside the four caves there was a presence of fresh stream of water source inside the Chamero and Bhalu cave. But water source was absent in both Sidha cave of Mohriya and Bhawar. Barr (1968) in his work describes the flooding of water source inside cave can have implications on temperature and humidity of caves. Some locations attract high numbers of bats where water sources and insects are abundant (Shrestha, 1997: Phuyal, 2005). The Chamero cave has the highest population with presence of exit which was absent in other caves. The roosting site inside Chamero and Bhalu caves were, wet and it had crevices where bats were roosting in a groups. It was dry inside the Sidha and Bhawar caves. The direction of the Sidha caves of Mohriya and Bhawar were facing north. The entrance of Chamero and Bhalu cave were facing Southeast and Northwest respectively; As described in a research study by Merlin *et al.,* (1977) within a given area, cave entrances on north versus south slopes, those at different elevations, and those on exposed surfaces versus in deep, protected valleys or sinks will face different ranges of surface temperature, which often result in detectable differences in internal temperatures and this will have implications on the roosting selection by cave bats.

The entrance of Chamero and Sidha cave was wide and larger while it was opposite in Bhalu and Sidha cave of Bhawar. The Bhalu cave was narrower and longer than other three caves in structure. While The Chamero cave was wider with declined slope at the entrance. The Sidha cave of Bhawar has inclined structure through the whole cave. As noted by Merlin *et al.,* (1977) the structure of cave itself determines the air flow inside cave which affects the cave temperature. According to Barr (1961) the geographic factor is the nature of the geological structure present inside caves which may have implications on the temperature and humidity of caves affecting the roosting selections. There was also a manmade gate at the entrance of the Sidha cave of Mohriya and Bhawar. So, these factors may be one of the reasons of absence of bats roosting inside these caves. In spite of the confusions in the existing literature a variety of factors such as number, size, and position of entrances, passage size, contour and slope, overall cave volume, distance of greatest volume from entrances, amount and seasonal timing of entry of surface water, air flow, and the annual range of outside temperature have been noted as a strong influencer to the cave temperature and humidity which affects the bat diversity (Halliday, 1954; Moore and Nicholas, 1964; Plummer, 1964; Cropley, 1965; Geiger. 1965; Peters, 1965; Vandel, 1965; Conn, 1966; Barr, 1968; Daan and Wichers, 1968).

The results of our study showed that there was not much variation in temperature and humidity (Appendix 4). The main important feature of cave is the variation in temperature which is further utilized by bats when selecting the roosting sites whereas, large caves are known to exhibit variations in temperature and relative humidity (Funakoshi and Uchida, 1978) and caves are generally regarded as having a temperature the same as the mean annual temperature of the surrounding area (Vandel, 1964; Dwyer, 1971). According to Harmata (1973) temperature constraints is of a critical importance for roosting selection only not for Bats but also for other cave dwelling organisms. Also, Twente (1955) noted that bats chooses roost with appropriate temperature for desired metabolic processes, warm for digestion and growth in the summer, and cool for torpor in the fall and winter, with the exact optimum temperatures varying somewhat among species.

Roost refugia selection is an essential part for bats survival and reproduction (Kunz, 1982; Tuttle and Stevenson, 1982). A study on Mexican cave bats shows that some bats require specific requirements for roosting Flores and Medellin (2004). Bats occupy a wide variety of roosts in both natural and artificial habitats. Roost selection of bats can vary seasonally and these serve a number of functions (Kunz, 1982). So, caves are also used by bats as a roosting site because they provide stable microclimate for roosts sites and protection from predators (Churchill *et al.*, 1997). In this study, the correlation between height of roosting refugia and bat population was found to be moderately correlated. While the correlation between bat population and distance of roosting refugia from cave entrance was found to be in a weak correlation (Table 4). This result shows bat population inside the Chamero cave increases with increase in height of the roosting refugia. Also, the results shows bat population does not increase with the distance of roosting refugia to the entrance. It shows that bat prefers to roost inside highest roosting refugia than in the lowest roosting refugia. Also the roosting refugia were found wet and damp on the highest regions with crevices. This may be the reason of preference to highest roosting refugia inside Chamero cave.

5.3 Diets of *Rousettus*

A total of 11 species of fruiting plants were identified as the potential diets of *Rousettus* in which 25% were found to be cultivated fruits and 75% were found to be wild fruits. Remaining five species are unidentified. The three species of all total species were observed during the foraging activities in which they feed on pollen, nectar or leaves. In Neo-tropics and Paleo-tropics plant visiting bats feeds on variation of plant parts including flowers, pollen, fruit, nectar, and leaves (Gardner, 1977; Marshall, 1983, 1985; Dobat and Peikert-Holle, 1985; Fleming, 1988, 1993; Law, 1992; Richards, 1995; Utzurrum, 1995; Tan *et al.,* 1998; Kalko *et al.,* 1996; Banack, 1998). Most frugivorous bats prefer to feed on the fruits due to their high energy carbohydrate content nonetheless, other plant parts like leaves, flowers, nectar and pollens are also consumed when the fruit resources are depleted (Heithaus, 1982). These bats also rejects seeds of several fruits despite their small size as they are rich in lipid contents because they have a hard covering and are difficult to digest (Dumont *et al.,* 2004). In a field observation by Handley (1991) in Lengteng sanctuary *R. leschenaultii* were found to be selecting the ripe fruits like figs and guava by sniffing. In this observation he also found that these bats extracted the juices from fruits by chewing them for 3-4 minutes and spat out the bolus. Bolus is the seeds and fibrous parts of the fruits which are separated by bats from only swallowing soft juicy and sugary pulp (Mickleburg *et al.,* 2001; korine *et al.,* 1999; Bonaccorso and Gust, 1987).This kind of behavior of *R. leschenaultii* was also seen on Jamaican fruit bat (*Artibeus jamaicensis* Leach, 1821) by Handley (1991). Such kind of behavior like spitting out the bolus by these bats allows them to get sugar rich fluid from fibers of fruits which apparently help them to conserve energy in further mastication of the fibrous parts of the fruits and its passage through gut (Goyal and Sale, 1992; Tedman and Hall, 1985). These bats generally feed on the ripe fruits because they are rich in nonstructural carbohydrates although they are low in fats and proteins (Mattson, 1980; Herrera, 1987; Martinez del Rio and Restrepo, 1993; Corlett, 1996). Bat feeding mainly on all fruit diets regularly suffered from nutrient deficiencies like protein, calcium, phosphorus and vitamin D (Buckland-Wright and Pye, 1973). These nutrients are found in other parts of the plants like leaves. Deficiency in these nutrients can cause retarded growth, decreased food consumption, osteoporosis and rickets, bone fractures, and ultimately reduced survivorship (Robbins, 1993; Favus, 1996). Also, it can cause large shear stresses and torsional loads during powered flight (Swartz *et al.,* 1992, Swartz, 1998), especially when females withdraw calcium from their bone reserves during lactation (Kwiecinski *et al.,* 1987; Bernard and Davison, 1996). So these nutrients may be a limiting nutrient for both survival and reproductive success (Barclay, 1994, 1995). Thus, these species also feeds on leaves of some plant species because leaves of some species are rich in important macro mineral (Raweiler, 1977; O'Brien *et al.,* 1998), where they gain access to these important nutrients of fruits and leaves by so called "wodging". This is a behavior that involves mastication and formation of an oral bolus of fiber or seeds as a wodge or spat swallowing the liquid fraction and expelling the fibrous pulp and seeds (Richards and Provic, 1984; Lowry, 1989; Zortea and Mendes, 1993; Kunz and Ingalls, 1994; Kunz and Kiaz, 1995; Tan *et al.,* 1998; Banack 1998). The important contribution of bats to the diversity of vertebrate's frugivorous communities and their ecological roles in tropical ecosystems is increasingly recognized. Bats plays major role in dispersal of seeds because of their species richness, high biomass, feeding habit and mobility of these fruit eating bats (Kunz and Fenton, 2005). Also that plant which depends upon the vertebrates for their seed dispersal and pollination supports the plant visiting bats. Most of the frugivorous bats feed on fruits, floral resources, seeds and leaves but in a given locality they prefer to feed on certain seasonal fruits with high nutritional value (Vanlalnghaka, 2015). *Rousettus leschenaultii* flies up to 6-10 km to forage (Tang *et al.,* 2010). Also, the large frugivorous bats, *Pteropus giganteus*, often fly up to 15 km or more for foraging. Foraging of bats depend on the food availability while some insectivorous bats concentrate foraging directly over or in the vicinity of water (Brigham 1991; Bogdanowicz 1994; Jaberget*et al*,. 1998). Thus, while feeding, these bats swallow small seeds and thereby assist in seed dispersal through their excreta over a vast area since they cover long distances from the roosting sites to forage for food (Vanlalnghaka, 2015).

This is why the value of tropical bats alone is enormous to our biodiversity. According to Tuttle (1997) seeds dropped by these bats can account up to 95 percent of forest re-growth on cleared land. Due to which these bats are the most important seed dispersing animal of both the old world and new world. Many economically important crop plants also rely on bats for survival such as commercially important products bananas, avocados, peaches, mangoes, breadfruit, figs etc. (Tuttle, 1997). As described by Fleming and Sosa (1994) some members of Stenodermatinae subfamily feeds almost on all fruits and plays major role in seed dispersers of many tropical trees and shrubs. According to Tuttle (1997) some bats also plays as keystone species in the lives of some plants which can be a crucial for the entire ecosystem. Many plants also attracts bats to take advantage of pollination such as the famous baobab tree of eastern African savannas blooms at night and using their unique odors and special flower shapes they attract bats and other pollinators. Also bats are the only animals which approach from below in a manner likely to get in contact with the flowers flower's reproductive organs in return plants reward them with nectar. While seasonal differences in diet are thought to lead to altitudinal movements of bats, as observed for instance by Giannini (1999), who studied the diet of *S. lilium* across an elevation gradient in Argentina.

5.3.1 Timing of bat emergence and return in relation with sunset and sunrise

Bat species usually emerge to feed after sunset and return before sunrise (Bateman and Vaughan, 1974; O'shea and Vaughan, 1977; Duverge *et al.,* 2000). Each observation on the emergence and return of bats was started approximately 30 minutes before the expected onset of sunset and sunrise. We observed the activities and timing of emergence and return for one week. Activity around the roost was visually monitored for the entire first night to record the beginning of the collective return and their behaviors. The time of emergence gradually increased and decreased according to the time of sunset. Likewise, the time of return gradually increased and decreased according to the time of sunrise.

As observed, bats were gathered in a small group of clusters within roost cavities. When the evening falls they start to become active. Then after 4-5 minutes of sunset they slowly start to emerge out of the cave but didn't take flight immediately. They roam around the entrance of the cave for 5-10 minute. The first group of the bats took flight after roaming. Then slowly other groups start to take flight. The emergence took place for about 15-20 minutes. The bats took flight straight to the jungle in North-East or South-West direction. The emerged bats scattered in the different directions to forage this may be to avoid the use of limited common resources. Arlettaz (1999, 1997) in his study described that animals may forage in different habitats and feed on different items to avoid the competition. Also, Bonaccorso *et al.,* (2006) animals tend to forage at different times. This behavior is described by niche theory which predicts that resource partitioning is necessary for the species to coexist but when they shared resources of animals are not limited then they may forage consequently and for longer periods (Zhang *et al.,* 2005).

Bats start to return 20-30 minutes before the sunrise. During the return of bats from foraging they roam around the forest near cave. They enter the cave then emerge out again. This behavior was shown by all the bats. The remaining few bats enters the cave before 2-3 minutes of sunrise. During the observation at evening some prey species of bats like snakes and owlets were seen around the cave so the roaming around entrance of cave before taking flight could be to avoid the risk of predation. A paper published by McWilliams (1989) and Speakman (1991) described the intrinsic biological factors such as predation risk may also impact the nocturnal activities of bats. The timing of return started 25-30 minutes before the sunrise and the timing of emergence started after 4-5 minutes of sunset. So, a later emergence and earlier returns may be is to reduce the risk of predation (Speakman *et al.,* 1995, Rydell *et al.,* 1995). But, the timing of emergence was late for one day. A study in all bat species to date the nocturnal activities and the timing of sunset and sunrise has been found to be in synchronization except for the Black bearded tomb bat (*Taphozous melanopogon* temminck, 1841) which is found in India (Erkert, 1982; Mcaney and Fairley 1988; Isaac and Marimuthu 1993; Catto *et al.*, 1995; Kunz and Anthony 1996). So, the late emergence may be due to the impact of raining (fig-6) that day which was also recorded by Mcaney and Fairley 1988) in their study. Also, some research shows that the timing and nocturnal activities of bats may be affected by environmental factors such as light levels (Lee and McCracken, 2001), prey abundance (Erkert, 1982), temperature (Catto *et al*., 1995), cloud (Kunz and Anthony, 1996).

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

A total number of four roosting sites have been identified from the study area of Bhimad. Total eight species of Bat had been found from study site with six families. The highest abundance of the bats was from Rhinolophidae family. The main roosting site of *Rousettus* was found inside Chamero cave. A total of seven roosting refugia of *Rousettus* were identified inside Chamero cave. The correlation between height of roost refugia and bat population was found to be moderately correlated. While the correlation between bat population and distance of roost refugia from cave entrance was found to be in weak correlation. This result concludes bats prefer roost inside the refugia with more height, damp and moist refugia. Bhalu cave and siddha cave 2 has the highest diversity of bats among other two caves. Bat diversity was found to be affected by factors such as distance to road, distance to water sources, distance to human settlement and cave length. A total of 33 plant species were collected as potential food of *Rousettus.* A total of 11 species of fruiting plant species were identified as the diets of *Rousettus.* Twenty five percent were found to be cultivated fruits and 75% were found to be wild fruits. This research study revealed that most of the frugivorous Leschenault's rousette bat feeds on wild fruits. The time of emergence gradually increased according to the time of sunset. The time of return gradually increased according to the time of sunrise.

6.2 Recommendations

On the basis this study following points are recommended:

- Detailed study on ecological relation between kastic environment andbat diversity can help understand the function of ecosystem.
- This site has a high diversity of bats so further study on ecological interactioncan enhance knowledge of locals for conservation.

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APPENDICES

Appendix 1- Morphometric measurements of identified bat species

S.N.	Species	Sex	BW (gm)	HB (mm)	T (mm)	HF (mm)	FA (mm)	2Ph 3Mt (mm)	E (mm)
1.	*Rousettus leschenaultii*	F	92	115.3	8.5	17.9	73.5	44.8	16.5
2.	*Rhinolophus affinis*	M	4	63.5	24.3	10.1	50.7	15.1	15.2
3.	*Rhinolophus pusillus*	M	35	35.5	16.3	6.2	36.2	15.5	16.5
4.	*Hipposideros armiger*	F	75	90.5	51.3	14.4	86	29.4	27
5.	*Miniopterus schreibersii*	F	14	61.9	16.1	7.2	47.9	37.8	10
6.	*Megaderma lyra*	M	70	86.3	21.1	12.7	64.7	22.5	32
7.	*Rhinolophus macrotis*	M	40	40.9	20.3	7.7	40.3	19.2	23.6
8.	*Myotis blythi*	F	50.3	70	55	12	55.5	54.3	20

Appendix 2- Potential food items of *Rousettus*

S.N.	Common Name	Scientific Name	Family
1.	Sacred fig	*Ficus religiosa*	Moraceae
2.	Roxburgh fig	*Ficus auriculata*	Moraceae
3.	Button tree	*Anogeissus latifolius*	Combretaceae
4.	Woodier wood	*Lannea coromandelica*	Anacardiceae
5.	Nepal fodder fig	*Ficus semicordata buch*	Moraceae
6.	Indian Rhodenderon	*Melastoma melabathricum*	Moraceae
7.	Artillery plant	*Pilea symmeria*	Urticaceae
8.	Crofton weed	*Eupatonium adenophorum*	Compositae
9.	False pareira	*Crissampelos pareira*	Menispermaceae
10.	Udumbara	*Ficus racemosa*	Moraceae
11.	Indian salmon	*Solanum surattense burm*	Solanaceae
12.	China berry	*Melia azedarach*	Meliaceae
13.	Fig tree	*Ficus glaberrina*	Moraceae
14.	Silk cotton tree	*Bombax ceiba*	Bombacaceae
15.	Banana	*Musa paradisiaca*	Caricaceae
16.	Mandarin orange	*Citrus reticulate*	Rutaceae
17.	Vegetable smart weed	*Aconogonum molle*	Polygonaceae
18.	Kadam	*Anthocephalus chinensis*	Rubiaceae
19.	Beggars stick	*Bidens pilosa*	Compositae

20.	Golden fig	*Ficus benjamina*	Moraceae
21.	Flora malesiana	*Helixanthera parasitica*	Loranthaceae
22.	Local mulberry	*Morus bombycis*	Moraceae
23.	Hairy nightsad	*Solanum villosum*	Solanaceae
24.	Papaya	*Carica papaya*	Caricaceae
25.	Hairy fig	*Ficus hispida*	Moraceae
26.	Large leaf maesa	*Mesa macrophylla*	Myrsinaceae
27.	Crape myrtle	*Lagerstroemia parviflora*	Lythraceae
28.	Hortensia	*Hydrangea robusta*	Hydrangeace
29.	Beauty berry	*Callicarpa arborea*	Verbenaceae
30.	Pakhuri	*Ficus glaberrima*	Moraceae
31.	Guava	*Psidiumguajava*	Myrtaceae
32.	Nepal Butter Fruit	*Aesandrabutyracea*	Sapotaceae
33.	Banyan Tree	*Ficus benghalensis*	Moraceae

Appendix 3- Correlation between populations of bats to the height, width of cave entrance

S.N.	Coefficient	t-value	df	p-value	Cor.
1.	Pop(HC)	1.48	5	0.19	0.55
2.	Pop(DC)	1.09	5	0.32	0.44

Appendix 4– Temperature and humidity inside different four caves

S.N.	Caves	Temperature (°C)		Humidity (%)	
		Maximum	Minimum	Maximum	Minimum
	Chamero cave	28.2	19.7	90	58
	Bhalu cave	25.2	24	74	70
	Siddha cave 2	26.7	25.4	83	67
	Siddha cave 1	29.6	26.1	75	64

Appendix 5- Emergence and return of bats with time of sunset and sunrise

S.N.	Time of sunset (PM)	Time of emergence (PM)	Time of sunrise (AM)	Time of return (AM)
1.	6:56	7:00	5:12	4:30
2.	6:57	7:01	5:12	4:33
3.	6:58	7:00	5:11	4:30
4.	6:59	7:06	5:11	4:29
5.	6:59	7:02	5:08	4:25

Appendix 6- Datasheet for different caves and their characteristics

S.N.	Roost/cave characteristics	Cave
1.	Location	
2.	Elevation	
3.	Height of the entrance	
4.	Width of entrance	
5.	Direction of entrance faced	
6.	Total Length of cave	
7.	Distance (entrance to colony)	
8.	Height (roosting site)	
9.	Temperature • Max • Min	
10.	Humidity • Max • Min	
11.	Light intensity • Max • Min	
12.	Roosting (cavity type)	

	• Hollow • Crevices	
13.	Roosting site condition • Wet • Dry • Damp / wet	
14.	Height of exit	
15.	Width of exit	
16.	Colony size	
17.	Distance of cave from water source	
18.	Distance of cave from cultivation	
19.	Distance of cave from human settlement	
20.	Distance of cave from Road	
21.	Water source inside the Cave	

Appendix 7- Data sheet for roost site selection in Chamero cave

S.N.	Left colony	Characteristics of cavity inside the cave		
		Distance from entrance	Height of the cavity	Cavity condition

PHOTO PLATES

Photo 1 -*Rousettus leschenaultii*

Photo 2 – *Rhinolophus affinis*

Photo3 **-** *Rhinolophus pusillus*

Photo 4-*Hipposideros armiger*

Photo 5 - *Megaderma lyra*

Photo 6- *Miniopterus schreibersii*

Photo 7 - *Rhinolophus macrotis*

Photo 8 - *Myotis blythi*

Photo 9 – Entrance of Chamero cave

Photo 10 - Entrance of Sidha cave

Photo 11 – Roosting cavity of *Rousettus*

Photo 12 – Group of *Rousettus*

Photo 13 – Learning Morphometric of Bat

Photo 14 – Measurement of Meta tarsal

Photo 15 – Seeds of Guava on dropping of bat Photo

16 – Seeds on dropping of bat

Photo 17 – Bat feeding on Haluwabed fruit

(Photo Courtesy – Arend Van Riessen)

Photo 18 – Local boy carrying pouch of bat fecal

Photo 19 – Spreading plastic sheets inside cave

Photo 20 – Pouch of Guano of Bat for fertilizer

Photo 21 – Guano of Bat on Rice field as fertilizer

Photo 22- Collected references of potential food items

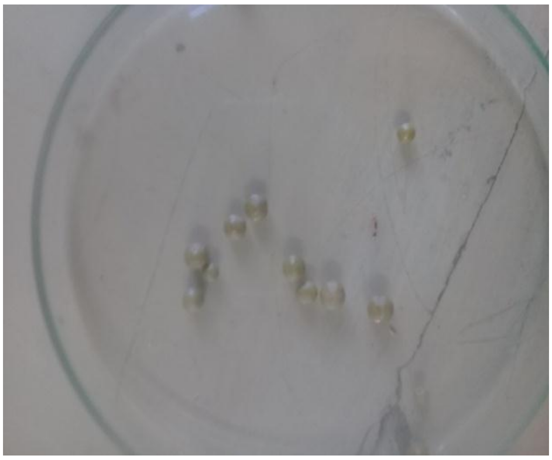

Photo 23- Fruit of *Ficus glaberrima*