FOOD HABITS OF INSECTIVOROUS BATS OF MAHENDRA AND NAGARJUN CAVES, NEPAL

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DECLARATION

I hereby declare that the work presented in this thesis has been done by myself, and has not been submitted elsewhere for the award of any degree. All sources of information have been specially acknowledged by reference to the author (s) or Institution (s).

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RECOMMENDATIONS

This is to recommend that the thesis entitled "Food Habits of Insectivorous Bats of Mahendra and Nagarjun Caves, Nepal" has been carried out by Mrs. Santosh Pokhrel for the partial fulfillment of Master's Degree of Science in Zoology with special paper Entomology. 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 others degree in any institutions.

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LETTER OF APPROVAL

On the recommendation of supervisor "Lecturer Mr. Prem B. Budha" this thesis submitted by Mrs. Santosh Pokhrel entitled "Food Habits of Insectivorous Bats of Mahendra and Nagarjun Caves, 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 Entomology.

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CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Mrs. Santosh Pokhrel entitled "Food Habits of Insectivorous Bats of Mahendra and Nagarjun Caves, Nepal" has been accepted as a partial fulfillment for the requirements of Master's Degree of Science in Zoology with special paper Entomology.

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LIST OF ABBREVIATIONS

C^o	Centigrade
CCINSA	Chiroptera Conservation and Information Network of South Asia
m.a.sl	Meter above sea level
mm	Millimeter
SMCRF	Small Mammal Conservation and Research Foundation
UNEP	United Nations Environment Programme

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ABSTRACT

Food habits of bats of Mahendra Cave, Pokhara and Nagarjun Cave, Kathmandu were studied using fecal analysis. Three white polythene plastic sheets (1 m x 1m size) were placed for 24 hours under the roosting sites of each cave on starting and ending days of March and September of 2011 to collect fresh bat droppings. All together 120 droppings (60 from each cave) were randomly selected, observed under stereoscope to identify insects orders and families. Altogether ten insect orders were reported *viz*. Coleoptera, Diptera, Hemiptera, Homoptera, Hymenoptera, Lepidoptera, Odonata, Orthoptera, Trichoptera and Thysanoptera. The identified families were included highest in Diptera (seven families), following Coleoptera (six families), Orthoptera (five families), Hymenoptera (three families), Hemiptera (three families) and Thysanoptera (one family). In addition, spider and mites were also reported. The percentage volume of the diet contained highest food items in Coleoptera (35.35%) and Orthoptera (24%) in Spring and Autumn respectively in Mahendra Cave. The other insects were Hymenoptera, Diptera, Hemiptera, Homoptera, Lepidoptera, Hymenoptera and Trichoptera. But in Nagarjun Cave, Diptera was major portion of the diet in Spring (28%) and Autumn (24%). The other food items belong to Orthoptera, Thysanoptera, Coleoptera, Hymenoptera including spiders and mites.

In Mahendra Cave, an average percentage of frequency of Coleopteran food items contained 63.33% followed by Orthoptera (46.66%) in Spring. But Orthoptera occupied (50%) followed by Coleoptera (26.66%) in Autumn. In Nagarjun Cave, Diptera was highest in both seasons. The diversity of insects consumed in Autumn and Spring in Mahendra Cave was more or less similar (H'-077 and H'-070) with Nagarjun Cave (H'-076 and H'-071) respectively.

1. INTRODUCTION

1.1 Background

Bats are the unique mammals due to their webbed forelimbs making them the only mammals naturally capable of true and sustained flight like birds. There are 1117 species of bat described all over the world occupying 20% of all mammalian species (Srinivasulu et al. 2010). They have been reported from all geographical areas of the world, except Arctic, Antarctic, extreme desert areas and a few isolated Oceanic Islands (Mickleburgh et al. 1992 and Huston et al. 2001). They are distributed mainly along the tropical belt of both the "Old" and "New" world. Traditionally, the Order Chiroptera is divided into two sub-orders; 1) Microchiroptera consisting 17 families and 931 species and sub-order 2) Megachiroptera consisting 186 species of Pteropoidae family (Mickleburgh et al. 1992, Koopman 1993, Simmons 2005, Hutson et al. 2010 and Srinivasulu et al. 2010). But recent molecular studies on bat species exhibit small bats are closely related with megabats and divided into two new suborders; 1) Yinpterochiroptera (includes the families Pteropodidae, Rhinolophidae, Megadermatidae and Rhinopomatidae) and 2) Yangochiroptera (includes all the remaining families) (Teeling et al. 2005). Some bat families are restricted to particular geographical areas viz. Old World (Pteropodidae, Rhinopomatidae, Hipposideridae, Myzopodidae and Mystacinidae), New World (families Noctilionidae, Phyllostomidae, Desmondontidae, Natalidae, Furipteredae and Thyropteridae) and only three families Emaballonuridae, Molossidae, Vespertilionidae are found both in the Old and New Worlds (Mickleburgh et al. 2002; Simmons 2005; Srinivasulu et al. 2010).

There are 128 species known from South Asia (Srinivasulu et al. 2010) occupying diverse niches in both natural and human modified ecosystems (Bates and Harrison 1997). There are about 53 species of bats reported from Nepal including 48 insectivorous species and 5 fruit eating species (Thapa 2010). The reported species occupied about 5% of world bat diversity and 40% of the South Asia.

In Kathmandu Valley, altogether 12 species of bats are known including two identified up to genius level only *Pipistrellus* sp. and *Myotis* sp. (Thapa 2010). The distribution of bats in Kathmandu ranged from 1267 m.a.sl (Pharping) to 1942 m.a.sl (Panimuhan). The bat assemblage was found to be rich in the sites at average altitudinal range of 1300-1500 m.a.sl like Nagarjun, Chobhar, Godawari, Bajrabahari and Chapagaun. The most widely distributed species which was reported from Godawari, Nagarjun, Nagarkot, Pharping is *Rhinolophus affinis*. *Hipposideros armiger* is the second most widely distributed species. It was reported from three sites Godawari, Nagarkot and Sundarijal.

Nagarjun cave area was occupied by *R. pusillus blythi* and *H. armiger* almost all the year but *Megaderma lyra lyra* and *Miniopterus schreibersii* were guest bats of this caves during winter (March-June) (Malla 2000).

Altogether 18 species of bats species belonging to five families and 11 genera are found in Pokhara Valley which covers 35% of total bat species known in Nepal from 12 different roosting places. Majority of bat species in Pokhara are insectivorous bats, belonging to the families, Megadermatidae (1 sp.), Rhinolophidae (5 spp.), Hipposideridae (1 sp.) and Vespertilionidae (8 spp.) (Adhikari 2008). The Mahendra Cave which lies in North part of Pokhara valley is occupied by three species of bats; *H. armiger***,** *R. affinis* and *R. ferrumequinum* **(**Giri 2009**).**

1.2 Bat Conservation

Bats continue to be among the most misunderstood and feared animals in human society. Many people still view bats as sinister, eerier and demonic creatures. Unfortunately, this reputation has caused bats harm and ill- treatment throughout the world. This superfluous fear and superstition has contributed to the almost total destruction of several bats species and has threatened the existence of many others (Phuyal 2007).

Bat conservation is the global concern in these days due to their declining natural habitats. This can be especially true on Island where they have to contend with cyclones and typhoons that can devastate their habitat. Bat in India, due to catastrophic loss of habitat, decreased foraging areas, reduced prey population forces bats to live in and around human habitation such as temples, tunnels and archaeological ruins.

Insectivorous bats eat flies, moths and others insects and play important role in natural control of pest insect population. Some bats also serve as pollinators and seed dispersion of many plants which is important to human. Their population is one of the best natural indicators of the health of our environment. This is because bats flourish where an ecosystem is healthy and stable (Jones et al. 2009).

In Europe, there is an agreement on the conservation of the population of European bats which came into force in 1994 and until now a total of 35 out of 63 range states have acceded to the agreement. Agreement aims to protect all 52 European bats through legislation, education, conservation measures and International co-operation with agreement numbers and with those who have not yet joined. The agreement provides a framework of co-operation for the conservation of bats throughout the Europe, Northern Europe and the Middle East http://www.eurobats.org) (UNEP 2011).

In South Asia, Chiroptera Conservation and Information Network of South Asia (CCINSA) has nearly 100 scientific members, involved in dissemination of information by organizing workshops, producing educational materials for schools and publish newsletters.

In Nepal, fundamental studies have been conducted by foreigners and recently some native researchers have been involved in conservation activities and received conservation award. Bat Friends and Nature-Nepal are the supporters for this work. Since 2005, however, a small but enthusiastic corps of students and others have been organizing "bat clubs", conducting preliminary research and working to educate our neighbour about the bats. Bats Conservation International has supported a number of those efforts. Different radio educational programmes were broadcasted by Rupendehi FM, Radio Annapurna Pokhara (93.4 Mhz), Radio Kantipur (96.1 and 101.8Mhz) or www.radiokantipur.com.

Similarly, Small Mammal Conservation and Research Foundation (SMCRF), Kathmandu, Nepal provides field supports to students for studying bats which help to conduct conservation programme such as art and essay competitions. Recently, SMCRF has placed bat boxes in different localities of Kathmandu valley as roosting for the bats.

1.3 Diet Analysis of Insectivorous Bats

Knowledge of an animal diet is important because the basic function of organism, its growth, development and reproduction take place at the expense of the food and all the other energy proceeds at the expense of the food (Nikolsky 1963). Thus the knowledge of the food habit helps to interpret its ecological role and its impact on local environment. Such knowledge is especially important as natural habitats are being altered owing to increased urbanization, modern agricultural practices (intense irrigation and pesticide application) and deforestation. In recent years, the use of pesticides is rapidly increasing. Thus, knowledge of their insect prey is important for assessing the potential value of bats in controlling insect pest, especially in areas where urban and cultivated lands have replaced natural habitats. Diet analysis can serve as background information for conservation measures.

There is limited number of observation on food habits of insectivorous bat species. However there are some publications on the diet of insectivorous bats in different country, (McAney et al. 1991, Whitaker and Yom-Tov 2001, Lacki et al. 2007 and Perlik et al. 2012)

In general, diet analysis of insectivorous bats can be done in two ways, i.e. using direct and indirect methods. The direct studie includes to analyze bat stomach by killing bats and indirect study includes analysis of their droppings. The examination of gut contents through the first method is restricted for population of many bat species which are threatened.

The analysis of bat dropping is now generally considered to yield reliable information on the diet of insectivorous bats without killing the species. Analysis of bat droppings is the reliable method of study to analyze food habit of insectivorous bats because of insect parts present in the droppings can be easily recovered and identified (McAney et al. 1991). Whilst fragments culled from prey and beneath a roosting place often provide useful information, unfortunately many small insects are eaten whole and rejectamenta are presumably biased in favour of items caught near the roosts. The extent of culling is rather unpredictable too, and depends on the degree of sclerotization of the food item and perhaps on how hungry a bat happens to be.

In fecal analysis, there are different ways of sample collection. Some researchers collect the sample on heavy-gauge in clear-white plastic sheets by lying under the roosting bats for long period of time and sample was selected randomly from the collection (McAney et al. 1991). Some researchers capture bats in monofilament nylon mist net placed on entrance of roost, measurements are taken, each bat is kept in a small cloth bag for certain period of time (15 min, 30 min, 1 hr) to collect feaces for dietary analysis (Lacki et al. 2007). Some researchers collect dried fecal materials from the top layer of the dropping (estimated to be 1-2 years old) in several places of the roost and placed in a plastic bag where they were mixed and randomly fecal droppings were selected from the collection for microscopic analysis (Whitaker and Yom-Tov 2001).

1.4 Objective of the Study

The principal aim of this study was to find out the diet composition of insectivorous bats of Nagarjun and Mahendra caves using fecal analysis, which will help to understand the ecology of the animal properly and create right way of conservation.

The following specific objectives were attempted to;

- identify different insects groups consumed by the insectivorous bats
- determine the percentage volume and frequency of the food items present in the bat droppings,
- compare diet composition in spring and autumn season in Nagarjun and Mahendra caves.
- prepare identification key for insect families found in the bat droppings.

1.5 Limitation of the Study

The sample was collected only two times in a month of March and September which represent the month of autumn and spring. The diet of the particular insectivorous bat species remains unknown because the droppings of different bat species are not distinguishable, because there are more than one species present in each cave. But published references/records of bat species of each cave are considered. Sample was not collected on other months of these seasons because both the cave are famous for tourists, in spring and autumn the flow of visitors were very high, the sheet can't laid on the ground. Likewise the culled material which sticks on the surface of dropping came under diet of bat not on reference because such parts were hard to see by eyes then when dropping were kept for softening these parts separate from dropping and came under diet. T-test was calculated for only the food item with sufficient data for calculation. The work is not purely taxonomic and the identification is limited based on the available text books and others literature which is not fully reliable to assure the correct identification.

2. LITERATURE REVIEW

The study of Nepalese bats was initiated by British residence to Nepal Brian William Hodgson in 1830s. Subsequently, major works were undertaken by Scully (1887), Hinton and Fry (1923, 1925), Sanborn (1950), Worth and Shah (1969), Frick (1969), Johnson et al. (1980), Abe (1971), Koopman (1983, 1993), Kock (1996). Altogether, 38 bat species were reported from Nepal till 1995 (Suwal et al. 1995). Soon, Bates and Harrison (1997) added more records on bat species of Nepal making a total of 49 bat species. Shrestha (1997) compiled distribution, and other taxonomic information of all 49 bat species. Molur et al. (2002) presented 51 species of bat from Nepal. The recent updated list of bat species consists of 53 species (SMRF 2010; Thapa 2010).

In Nepal, first of all Malla (2000) carried out the diet analysis of insectivorous bats of Nagarjun cave, Acharya (2006) worked on distribution of roosting and survival threats of bats in Pokhara valley, Thapa (2008 and 2009) reported flying fox colonies from Eastern Terai. Thapa and Thapa (2009), Giri (2009), Ghimire et al. (2010) documented the population, distribution, behavior of different Nepalese bat but in world various works had been done in different aspects of bats.

Dalton et al. (1989) found moths and beetles as dominant insects in the diet of *Plecotus townsendii*. But Neill and Tayler (1989) studied eight species of Tasmanian bats and detected Lepidoptera as major component and Coleoptera being the most important item in selective feeder only. In summary, consumption of insects by insectivorous bats particularly depends on the availability of food in the surrounding environment which varies in different locations and bat species in the world as shown in Table.1.

Table 1 : Summary of food habits of insectivorous bats

Finding	**References**
Moths comprised dominant insects followed by beetles in *Plecotus townsendii* in Virginia.	Dalton et al. (1989)
Coleoptera and Lepidoptera include highest number consumed by Tasmanian bats.	Neill et al. (1989)

Ephemeroptera, Dermatoptera, Hemiptera, Neuroptera, Lepidoptera, Diptera, Coleoptera and Hymenoptera were reported in bat diet in Ireland and England.	McAney et al. (1991)
Diet of *Myotis lucifugus* in Central Alaska consumed 71.1% moths followed by spiders 16.8%, and mosquitoes 1.8%.	Whitaker and Lawhead (1992)
The diet composition in different bat species viz. *Myotis nattereri, Pipistrellus bodenbeimeri, P. kublii, P. rueppelli, Plecotus austracus, Otonycteris hamprichi, Rhinolophus divosus* and *Tadarida teniotis* included Coleoptera (59 %), Hymenoptera (21%), Orthoptera (14%), Lepidoptera (3%), Diptera (2%) and Odonata (1%) in Israel.	Whitaker and Tomich (1993)
In Southern Illinois, Coleoptera (68.1%) was primary food in Evening Bat and Red Bat (68.7%).	Feldhamer et al. (1995)
Lepidoptera (33.6%), Coleoptera (26.4%), Hymenoptera (20.5%) and Diptera (14.5%) comprised the main bulk of the diet of *Tadarida brasiliensis* bat in Mexico. Other taxa represented by less than 6% volume.	Kunz et al. (1995)
The diet of *Kerivoula papuensis* composed of spider (Araneida) 99.1% and others were Coleoptera, Lepidoptera and Diptera.	Schulz and Wainer (1997)
Nine orders of insects reported from bat diet include Lepidoptera, Diptera, Neuroptera and Coleoptera in *Pipistrellus pipistrellus* and *Rhinolophus hipposideros* in Switzerland.	Arlettary et al. (2000)
Percentage volume of Coleoptera and Lepidoptera varies in different species such as Coleoptera was higher in *Hipposideros* but Lepidoptera in *Rhinolophus*. Others were Orthroptera, Hymenoptera, Hemiptera and Diptera in the diet of bats of Nagarjun cave, Kathmandu.	Malla (2000)

In Northern Israel, Coleoptera was the most abundant food item in *Rhinolophus microphylum* (80%) and 51% in *R. hardwickei*. Formicidae 30.4% in *R. hardwickei*. Others were Lepidoptera, Diptera and Orthoptera .	Whitaker and Yom-Tov (2001)
Lepidoptera was the greatest percentage volume of any insect by most species; Coleoptera was also eaten at high level by bats in North-Central Idaha.	Lacki et al. (2007)
In Japan, *Rhinolophus perditus* consumed Chironomids (Diptera) as dominant insects followed by Coleoptera, Lepidoptera, and Hymenoptera. But Coleoptera, Trichoptera and Lepidoptera were main food of *Hipposideros*. In *Minipterus*, Hymenoptera was more frequent but Diptera was abundant.	Fukui et al. (2009)
In Britain and Irish range, *Rhinolophus hipposideros* consumed mostly Diptera (abundant order), Sphaeroceridae (abundant family followed by Trichoceridae, Mycetophilidae and Scathophagidae) and others were Lepidoptera, Neuroptera, Araneidae and Acari.	William et al. (2011)

3. MATERIALS AND METHODS

3.1 Study Area

Two caves were selected for this study. The Nagarjun Cave is located in Kathmandu Valley and Mahendra Cave is located in Pokhara Valley.

3.1.1 Nagarjun Cave

Nagarjun forest is situated on the Northern most boarder region of Kathmandu valley, lying in 27˚45" latitude, 85˚15" longitude and 1690 m in elevation. Its total area is approximately 15 sq.km and lies between Kathmandu and Nuwakot districts. It is nearly 8 km far from Kathmandu proper across the Vishnumati River. The main range of the Nagarjun hill runs in east west direction with its highest point in Jamacho 2188 m. Many spurs of the hill run in different direction forming gullies and narrow valleys. Southern side of the hill is forested with hard wood trees. This forest is one of the scenic beauties of Kathmandu valley and comes under Shivapuri Nagarjun National Park. The Nagarjun forest is rich in various types of wild life resources. The main wild fauna are Leopard (*Panthera pardus*), Wild Boar *(Sus scrofa*), Common Langur (*Semnopithecus schistaceus*), Himalayan Yellow Throated Marten *(Martes flavigula*) etc.

The intensive study area is the cave of Nagarjun hill. This cave lies just outside the boundary and northern part of the protected area and can easily be seen from the main road. This cave is used by the bats. The bats are easily seen by the cave as they hang down from the wall of the cave with their wrapped around them. These bats seem to make cluster of only few inches apart. The floor of this cave is covered with guano (bat feaces). There is only one entrance to this cave and its height is about 2 m but just after this entrance, the height of cave reaches about 30 m and gradually narrowing inside, where the height of cave reaches only about 1.5 m just after walking for about 20 minutes from the main entrance of the cave. The total length of the cave is about 400 m and there is a small pond at the end of this cave. The temperature of this cave is about 5-6 degree centigrade more than the outside temperature during winter i.e. 18˚-23˚C at noon time. The inner part of the cave where men don't visit and where only few bats are seen in hanging position, there is large accumulation of guano on the floor of the cave which indicates a long use of cave by the bats. The area has rainy summer and dry winter. The northern side is highly forested and sunny but drier southern side. The climatic data of Nagarjun is taken from adjoining station i.e. Nagpokhari as graphic representation. An average annual precipitation was estimated to be 123.36 mm for the period 2007 to 20011. Precipitation ranged from average maximum in August and minimum of 0mm in January during 2007 to 2011. The monsoon rain typically begins from May and reaches peak during June-July and continues till September. The annual rainfall pattern and mean yearly maximum and minimum temperatures recorded from 2007 to 2011 shows an average maximum temperature of 30.6˚C in the month of June and minimum of 3.7˚C in January.

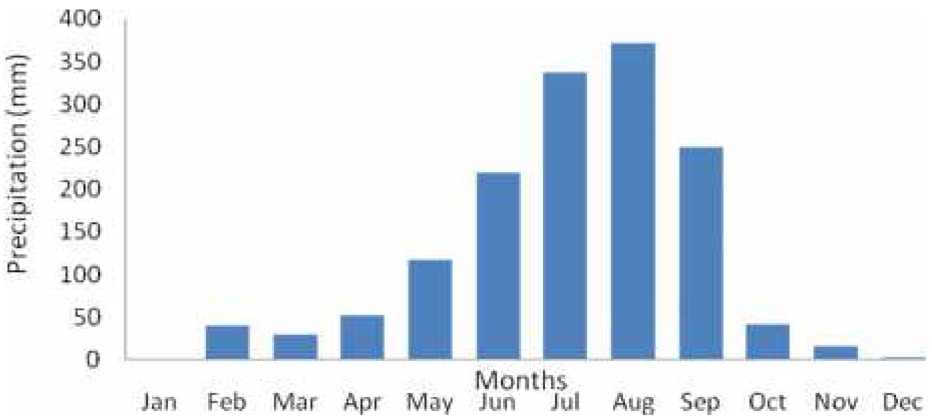

Figure 1 : Mean annual precipitation for 2007-2011 nearby Nagarjun

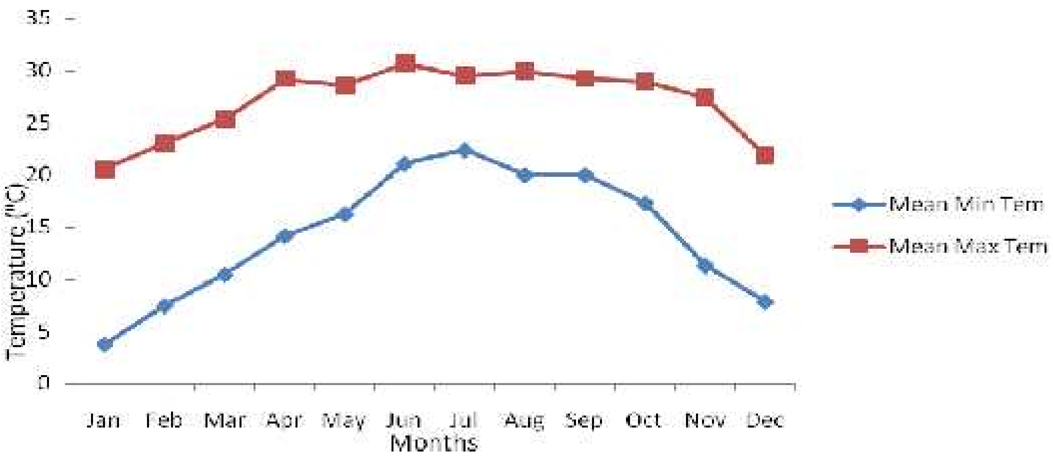

Figure 2 : Mean annual temperature for 2007-2009 recorded nearby Nagarjun

Figure 3: Location of Nagarjun Cave

3.1.2 Mahendra Cave

Pokhara is situated in the northwestern corner of the Pokhara valley which is a widening of the Seti Gandaki valley that lies in the midline region of Himalayas at 83^{0}40' to 84^{0}12' latitude and 28^{0}6' to 28^{0}36' longitude. Altitude ranges from 450 m to 7,969 m from sea level. As a result of this sharp rise in altitude the area of Pokhara has one of the highest precipitation rates in the valley to 5600 mm per year between the southern and northern part of the city, the northern part of the city situated at the foothills of the mountains experiences proportionally higher amount of precipitation. The porous underground of the valley favours the formation of caves and several caves can be found within the city limits. Nearly, 35 species of mammal are found in Pokhara valley. The mammals are commonly found in the forest around Pokhara but occasionally seen due to lower population and their shy nature as compared to avifauna. Hence patience is required to watch these mammals. The best places to observe these animals are the forests near the Begnas Lake, Rupa Lake, Banpale hill etc. Some species are Common Leopard *(Panthera pardus*), Common Otter *(Lutra lutra*), Clouded Leopard (*Neofelis nebulosa*), Bengal Fox *(Vulpus bengalensis*), Chinese Pangolin (*Manis pentadactyla),* similarly avian fauna are

Blue-throated Barbet *(Megalaima asiatica*), Black-naped Woodpecker *(Picus affinis*), House Crow *(Corvus splendens*), Gray tit (*Parus major*) etc.

Pokhara is famous for limestone cave such as Mahendra cave, Bat cave, Gupteshwar Mahadev cave and others. The Mahendra cave is situated about 7 km north of Prithvichok at Batulechaur. The cave was named Mahendra cave in 1960 A.D. when it was inaugurated by King Mahendra. The cave is located $83^0$58'45.7" E, $28^0$16'19.6" N at an altitude of 962 m. Light bulbs have also been fitted for easy observation of the cave while there is also the arrangement of back up light during the power cut hours. Tourists are advised to stay calm while entering the cave. A person can easily enter the cave until 125 m ahead. There is more than one way to exit from this cave but it's quite difficult. Bats are not seen on the ceiling of the cave where visitors usually visit because of disturbances and lighting system inside the cave. But there is a divergent path from main way inside the cave where the visitors are not allowed and no facility of lighting holds large number of bats. The climate of the city is sub-tropical; however, the elevation keeps temperature moderate; summer temperature average between 25 to 35˚c, in winter around 4- 15˚c. Pokhara and nearby areas receive a high amount of precipitation during the monsoon season (July-September), winter and spring skies are generally clear and sunny.

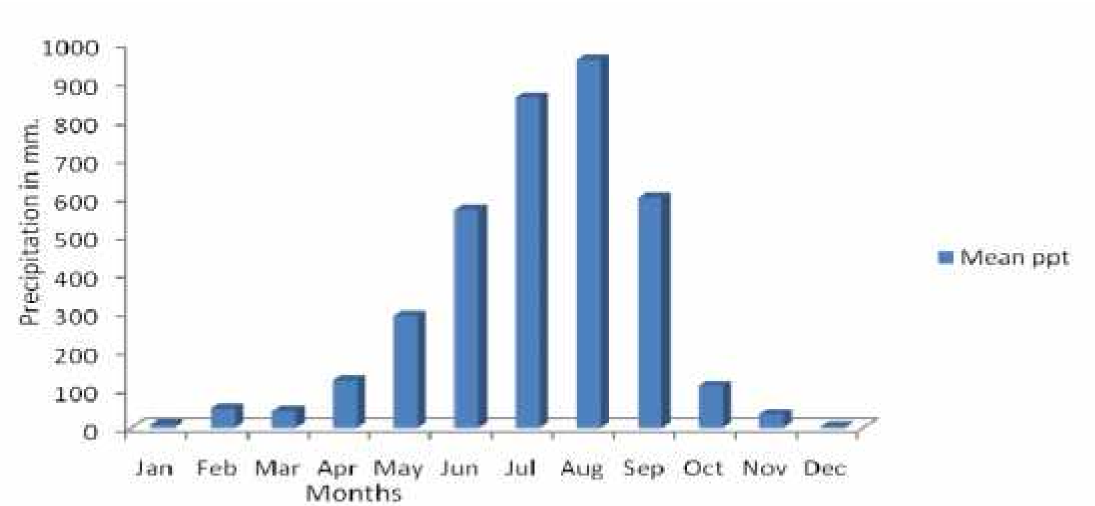

Figure 4 : Mean annual precipitation for 2007-2011 recorded nearby Mahendra Cave

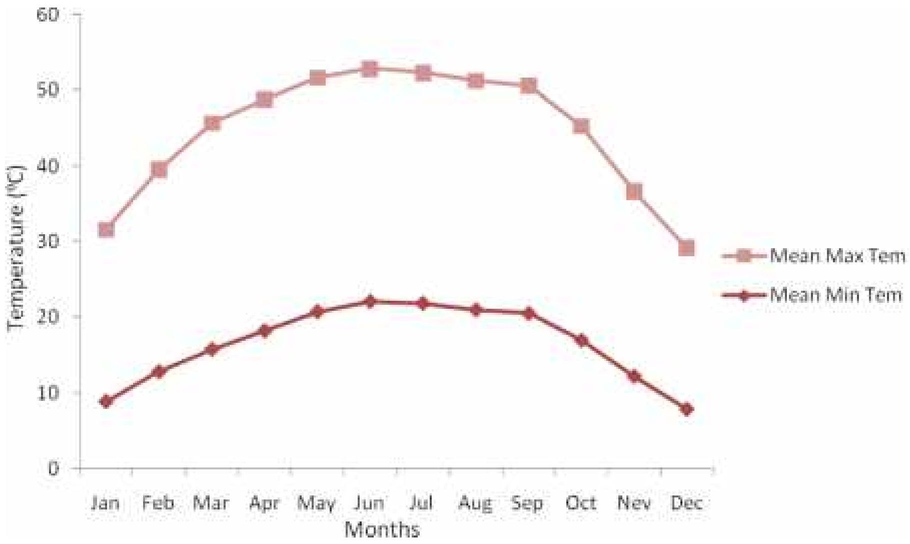

Figure 5 : Mean annual temperature for 2007-2011 recoded nearby Mahendra cave

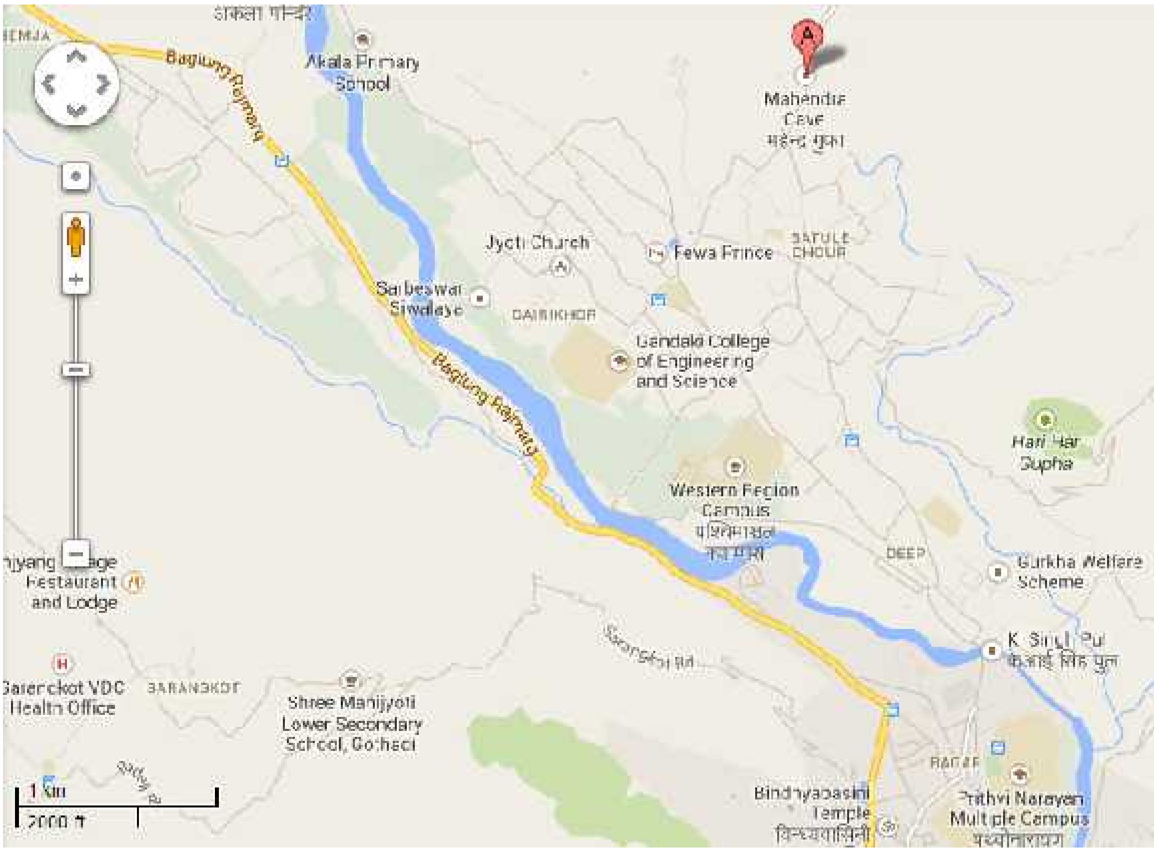

Figure 6: Location of Mahendra Cave

3.2 Fecal Sample Collection

Dropping were collected on heavy-gauge clear and white polythene sheet on March and September 2011. Thickness prevents breakage and black polythene was avoided as it was difficult to spot things on it. So, white polythene plastic was laid on the floor of the cave. The size of the polythene was 1m ×1m which was the appropriate size according to the structure of the cave floor. Such plastic sheets were laid on three different places of a cave for 24 hours only. The sample collected for 24 hr can represent the diet composition of bats. The studied caves were highly visited by tourist so sheet cannot be laid for longer time. By same process samples were collected twice in a month and of two seasons in a cave, firstly in starting day of March and secondly in ending day of same month of 2011 which represents the diet of autumn season and for spring, sample was collected on starting and ending days of September. The sheets with dropping of bats were carefully folded up, removed and later sorted in good light against a white background for feces and culled fragments. The fecal samples were stored in air-tight vessel with screw cap, which contains two folds of cotton. The cotton was soaked in ethyl alcohol for preservation of sample and moisture also. The sample was carried to the lab for further investigation.

3.3 Sample Preparation

All the fecal material from six places of a cave were mixed up and 30 dropping samples were selected randomly and kept in a Petri dish containing hot water and few drops of glycerol for 24 hours following the protocol (Kunz 1988). The droppings were broken into fine pieces carefully with the help of fine dissecting needles under stereo-binocular microscope. The separated parts of insects were observed under stereomicroscope.

3.4 Preparation of Slides

The insect fragments which were recovered from the droppings were mainly legs, wings, antenna, eyes, mouth parts because they were highly sclerotized in insects. Those parts were dehydrated. The dehydration was done through a series of alcohol (30%, 50%, 70%, 90% and 100%) and finally treated with alcohol, xylene series (3:1, 1:1, 1:3). The dehydrated sample was then blotted on tissue paper before transporting to xylene and finally mounted in glycerinated gelatin or sometime in transparent nail polish. The slides were photographed with PC-digital camera connected with computer. All the slides were submitted on Central Department of Zoology.

3.5 Identification

Structures and characters recovered antennae, legs, wings, mouth parts, and other body parts of insects were studied and compared with available literature, textbooks such as (Vanemden 1965; Bingham 1975; Distant 1977; Jacoby 1975; Richards and Davies 1977 and Borror et al. 1981). All parts are identified up to order and family level.

3.6 Analytical Calculations

3.6.1 Percentage Volume of Prey Taxa

The food items in droppings of bats were found too finely chewed and mixed. So, percentage volume couldn't be measured by displacement in water. Therefore visual estimate was made for each food category as mentioned by Whitaker (1988).

The average percentage volume i.e. the average percentage by volume of each food type in the total sample was calculated by using the following formula:

$$\%\text{Volume} = \frac{\text{Sum of Individual Volumes}}{\text{Total Volume of the Sample}} \times 100$$

where,

%V= the overall percentage volume

3.6.2 Percentage Frequency of Prey Taxa

The percentage occurrence of prey taxa is defined as the number of dropping in which food items occurred. The average percentage occurrence of different dietary items was determined in percentage. The number of dropping with particular food items (N_2) were examined and percentage of occurrence of each food items (N_1) was determined in different season of the year. This was helpful to know the proportion of bats eating a particular food item in different seasons. It was determined by using the formula given by Windell (1971).

$$\%F = \frac{N_2}{N_1} \times 100$$

where,

%F	=	Percentage frequency of prey taxa.
N_2	=	No. of droppings with particular food items.
N_1	=	Total no. of droppings examined.

3.6.3 Diversity of Food Items in Bat Droppings

The indices of food niche breadth (Krebs 1989) namely Shanon-Wiener index (H') is calculated as follows:

$$H' = -\Sigma p_i \log p_i$$

Where,

p_i is the proportion of its food type in the diet.

3.6.4 Comparison of Insect Food Composition in Two Sample Caves

t- test is used to compare two different set of values. It is performed on a small set of data (N= less than 30) and generally applied to normal distribution. It uses means and standard deviation of two samples to make a comparison and the formula is:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}}$$

Where,

$\bar{x}_1$	=	mean of first sample
$\bar{x}_2$	=	mean of second sample
s_1^2	=	standard deviation of first sample
s_2^2	=	standard deviation of second sample
n_1	=	total numbers of first sample
n_2	=	total numbers of second sample

4. RESULTS

4.1 Insect orders in bat dropping analysis

Altogether 120 dropping samples of bats in Mahendra Cave and Nagarjun Cave were analysed. Ten insect orders and one Araneae and one Acari were identified in the dropping of bats in both caves. Some parts remains unidentified which were considered as others. Among identified orders Mahendra Cave includes seven orders in Spring and eight in Autumn. Similarly, Nagarjun Cave includes six orders in both seasons. Thysanoptera was absent in Spring but present in Autumn in both caves. Orthoptera, Coleoptera, Diptera and Hymenoptera were found in both seasons in two caves. Occurrence of Lepidoptera and Trichoptera in Spring and Autumn season was noted in a single dropping sample from Mahendra Cave but Odonata, mite and spider were reported in single dropping samples from Nagarjun Cave. Altogether seven insect orders in 30 dropping samples of Spring and eight insect orders in 25 dropping samples of Autumn season were identified from Mahendra Cave. Likewise six orders of insect were found only in 21 droppings in Nagarjun cave in each season. Coleoptera, Orthoptera, Diptera and Hymenoptera were insect orders found in large number of droppings than other insect orders in both seasons of the two caves (Table. 2).

Table 2 : Total number of insect items (N= 120 droppings) and no. of positive droppings

Order	Total no. of items in droppings				No. of positive droppings			
	Mahendra cave		Nagarjun Cave		Mahendra cave		Nagarjun cave	
	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autu mn
Thysanoptera	0	10	0	10	0	3	0	7
Hemiptera	2	3	2	0	1	2	2	0
Homoptera	2	1	3	0	2	1	3	0
Orthoptera	20	22	7	6	14	15	5	3
Lepidoptera	1	0	0	0	1	0	0	0
Coleoptera	35	17	7	7	19	8	4	5
Trichoptera	0	1	0	0	0	1	0	0
Diptera	11	21	13	10	10	10	8	7

Odonata	-	-	-	1	-	-	-	1
Hymenoptera	21	2	7	2	13	1	7	2
Acari/Araneae	0	0	0	2	0	0	0	2
Others	9	14	8	4	8	13	3	4
Total	101	91	47	42	-	-	-	-
Null dropping	-	-	-	-	0	5	9	9

4.2 Insect Families in Sample Droppings

Altogether 25 families of insects were identified in the bat droppings of Nagarjun and Mahendra caves. Among them Diptera was order with highest number of families seven. Muscidae of Diptera was found in both caves in two seasons and Culicidae was also found in all except Autumn of Nagarjun. Chironomidae and Tabanidae were only identified in autumn and Spring of Mahendra cave respectively. Psychodidae and Cecidomiidae were only in spring of Nagarjun. Coleoptera was with six families i.e. Carabidae, Scaraebidae and Coccinellidae were found in spring but Cerambycidae and Chrysomelidae were found in autumn at Mahendra cave. In case of Nagarjun cave, Chrysomelidae and Cerambycidae were presented in spring where Curculionidae was only found in autumn. Orthoptera was order with five families each. All five families of Orthoptera were present in Mahendra cave in spring but in autumn only three families (Acrididae, Blattoidae and Gryllidae) were found. In Nagarjun cave, Blattoidae and Tettigoniidae were identified in spring and only Blattoidae in autumn. The other orders Hemiptera and Hymenoptera consist of three families each. Cicadellidae of Hemiptera was noticed on both seasons of Mahendra cave in addition Pentatomidae was also in autumn. Single family i.e. Miridae was found at Nagarjun cave in spring and none of the families were noticed in autumn. Autumn season of two caves contained only Thripidae family of Thysanoptera. Insect families identified in bat dropping are represented in Table 3.

Table 3: Identified insect families in bat Droppings of Nagarjun and Mahendra Caves

Order	Mahendra cave		Nagarjun cave		Identified families
	Spring	Autumn	Spring	Autumn	
Thysanoptera	0	1	0	1	Thripidae

Hemiptera	1	2	1	0	Cicadellidae, Pentatomidae and Miridae
Orthoptera	5	3	2	1	Gryllidae, Acaridae, Tettigoniidae, Phasmidae and Blattidae
Coleoptera	3	2	2	1	Carabidae, Scarabaeidae, Coccinellidae, Curculionidae, Cerambycidae, and Chrysomelidae
Diptera	4	3	4	1	Culicidae, Muscidae, Syrphidae, Tabanidae, Cecidomiidae Chironomidae and Psychodidae
Hymenoptera	3	2	3	1	Ichneumonidae, Apoidae and Chalcidae

4.3 Percentage Volume of Prey Taxa

In Mahendra Cave, Coleoptera that was the dominant group with 35.35% following Hymenoptera (21.21%) of total volume of food items in Spring while Orthoptera comprised dominant 24% in Autumn including Diptera 11% and 23% in Spring and Autumn respectively. Other insect orders were Hemiptera, Homoptera, Lepidoptera and Trichoptera including unidentified items 9% and 16% in Spring and Autumn respectively (Figure 7).

Similarly in Nagarjun Cave, Diptera was found to be the most dominant prey category containing 28% of total volume in Spring but Diptera and Thysanoptera (24%) as dominant group in Autumn. Other food items in significant amount are Orthoptera, Hymenoptera and Coleoptera each occupying 15% of total volume. Likewise Odonata Acari and Araneae were found only in autumn season (Figure 7).

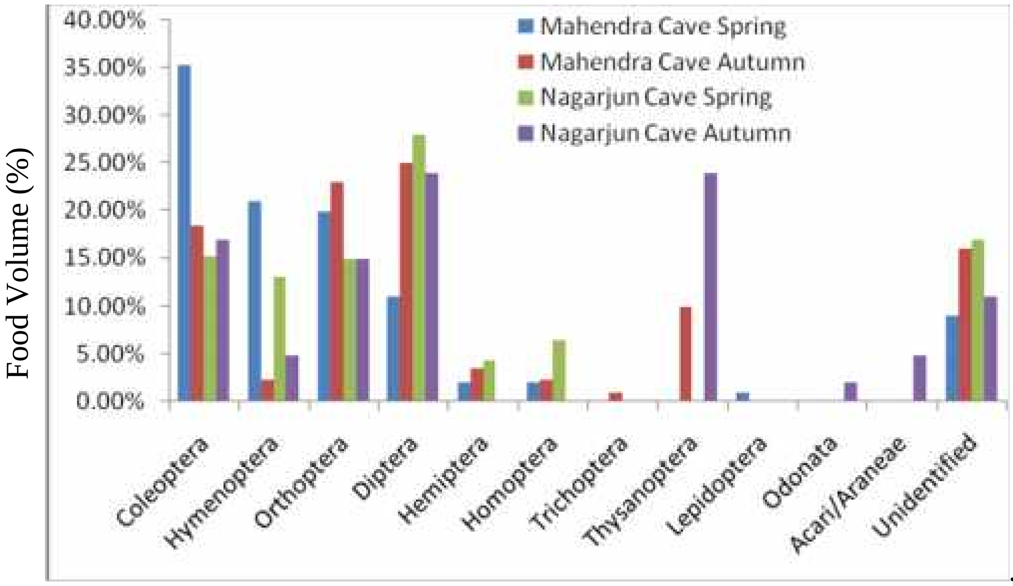

Figure 7: Percent food volume of prey taxa in Mahendra cave and Nagarjun cave.

Coleoptera contained a major food composition following Hymenoptera, Diptera and Orthoptera in Spring but Diptera, Coleoptera, Orthoptera and Thysanoptera in Autum season. An average percent volume of prey items in two caves in two seasons is represented in Figure 8.

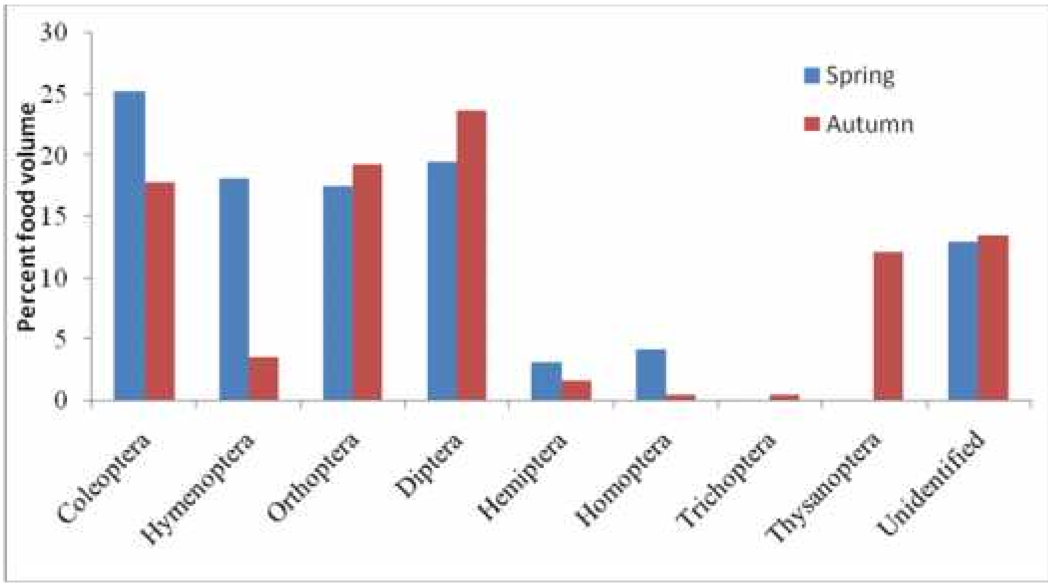

Figure 8: Average food items in Srping and Autumn Seasons

4.4 Percentage Frequency of Food Items in Bat Droppings

In Mahendra cave, Coleoptera was with 63.33% of occurrence following Orthoptera with 46.66% and Hymenoptera (43.33%) of occurrence in Spring while in Autumn, Orthoptera was with 50% of occurrence following Coleoptera with 26.66%. Diptera was found with 33.33% of occurrence in both seasons. Homoptera, Hemiptera, Lepidoptera, Trichoptera and Thysanoptera were with least percentage of occurrences (Table 9). A total of 27% and 46.66% of frequency of occurrence were carried by unidentified items in Spring and Autumn respectively.

In Nagarjun cave, the percentage of frequency of occurrence was highest in Diptera with 27% and 23% in Spring and Autumn respectively with Thysanoptera in Autumn. Others Orhtoptera , Hymenoptera and Coleoptera were with higher percentage of frequency while Homoptera, Hemiptera, Odonata, Acari and Araneae were with least percentage of occurrence (Table 9). The unidentified item carried 10% and 13.3% of occurrence in Spring and Autumn respectively.

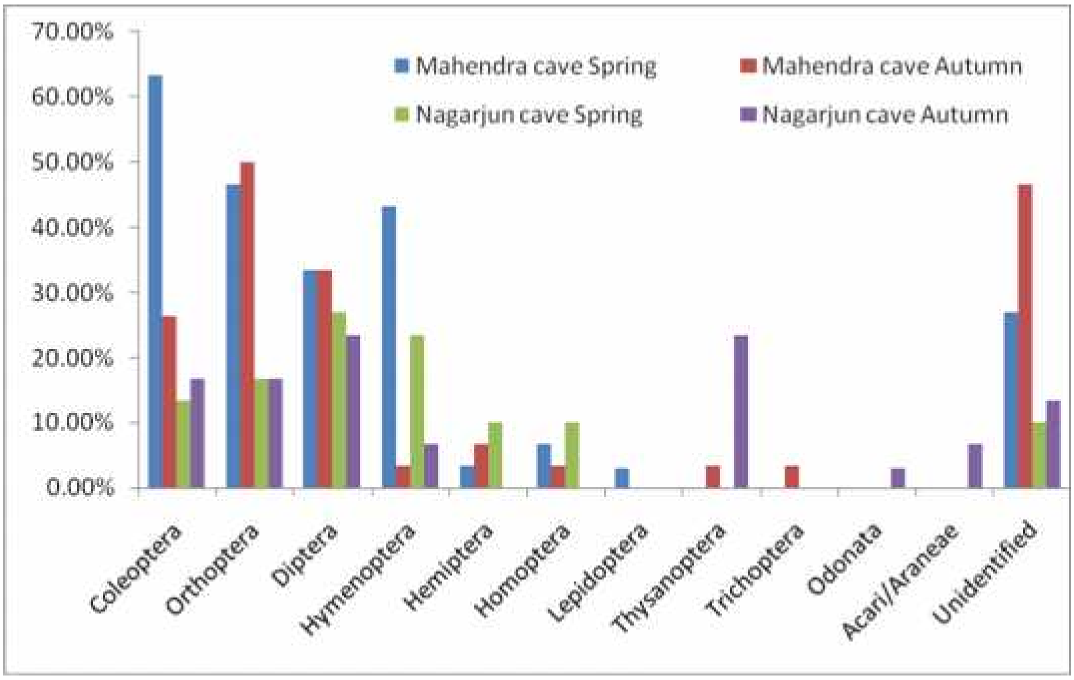

Figure 9: Percentage frequency of food items

4.5 Diet Diversity and Seasonal Variation in Food Niche Breadth

Shannon Wiener' diversity Index (H') of insect food in Mahendra and Nagarjun caves is represented in the following (Figure 10). The diversity of insects consumed by bats was slightly greater in autumn than spring.

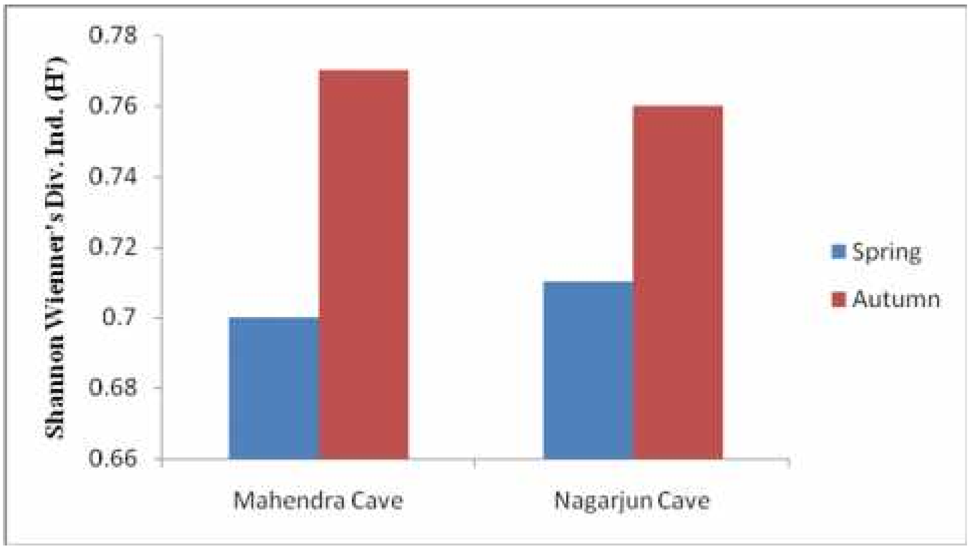

Figure 10: Shannon's Diversity Index food item in insectivorous bats

4.6 Comparison of Insect Consumption by Bats

For calculation of t-test of this work, the null hypothesis i.e. there is no difference in mean of consumption item in two seasons ($u_1 = u_2$) was set in degree of freedom of five (d.f = 5).

The table 6 with tabulated t-value 2.01 indicates that, there was no difference in the consumption of Orthoptera, Diptera, Coleoptera as well as whole insect items by bats of both caves in two seasons i.e. the null hypothesis is accepted but in Hymenoptera null hypothesis is rejected i.e. there is significant difference in the consumption of Hymenoptera by bats of both caves in two seasons.

Table 4: Relation of food items identified from bat droppings in Spring and Autumn (t-test, tabulated value 2.01)

Insect Order	Nagarjun cave		Obtained value	Mahendra cave		Obtained value
	Spring	Autumn		Spring	Autumn	
Orthoptera	7	6	-0.41	20	22	-0.77
Coleoptera	7	7	0.0	35	17	1.89
Diptera	13	10	0.78	11	21	-1.89
Hymenoptera	7	2	2.11	21	2	4.053
Others	13	16	0.92	14	29	-1.39
Whole items	47	41	0.15	101	91	0.001

4.7 Key to Identify Prey Insects in Bat Droppings

Identification key is based on characters of insect parts recovered in bat droppings of Mahendra and Nagarjun caves. A dichotomous key to insect orders and families is represented as follows;

1. Body with 4 pairs of legs, legs hairy, wings absent… . ………….……... …..…..2
   Body 3 pairs of legs, wings present…………………… ……………………..…..3

2. Body oval, four pair of legs, anteriorly directed mouth parts (Fig. 11A, B).....Mites
   Leg long and hairy (Fig. 13E) ……………………... ….……….................Spider
3. Scales on wing present, fecal contents often contain mass of scales spread (Fig. 12B) ……………………..Lepidoptera
   Scales on wings absent……………………………………………………….…….4
4. Wing hard or leathery and colourful body …………. Coleoptera (Fig. 12L) or Heteroptera (Fig. 12K) ……..5
   Body usually soft, wing membranous or fringed………………………………18
5. Tarsi with 4-5 segments, tarsal claws present (Fig. Fig. 3 J, P) without spine, antennae varied shaped viz. lamellate (Fig. 13 A,D), filiform, …Coleoptera…..6
   Tarsi 2 or 3 segmented, hemelytra present, long hairy or spiny leg Hemiptera/ Heteroptera ………………..14

Coleoptera

6. Leg with notch……………………………………….…………………………............7

Leg without notch……………………………………………………………………….8

7. Leg long and spiny (Fig. 13I), antennae long and composed of series of cylindrical segments …………………………………………………………...Carabidae

8. Front tibia dilated…………………………………………………………..…...9

Front tibia not dilated……………………………………….………………..11

9. Antennae with plate like structure forming compound club (Fig.13A, D)..Scarabaeidae

Antennae without plate like structure………………………………… …...10

10. Beetle often very heavy; elbowed antennae present (Fig.13C)……..Curculionidae

11. Tarsal claw clefted with hair (Fig 13O)……………………………..Cerambycidae

Tarsal claw toothed at base………………………………………...Coccinelidae

Heteroptera

12. Hemelytra present, anterior portion of hemelytra contains two closed cells (Fig.11L)…………………………………………………………….Miridae

Without punctae on hemelytra…………………………..............................13

13. Long hairy leg…………………………………………..…...Pentatomidae

Leg with spine……Orthoptera….. 24, Homoptera……………………………14

14. Hind tibia with 1 or 2 rows of spines, hind coxae transverse……..…Cicadellidae

15. With membranous or parchment- like wings…………………………………..16

Wing with comparatively less longitudinal veins…………………………….. 17

16. Wings with simple venation, few cross veins, can often distinguish parts of R, Cu, M or Oral veins (Fig 12A, I,)……………………………...True flies…. (Diptera)

More complicated venation, often with numerous cross veins, more difficult to determine identification of specific veins (Fig. 12 F)…………………Odonata

Diptera, Hymenoptera, Thysanoptera and Trichoptera

17. Anal vein straight gently curved; the anal cell closed at or before wing margin; hind tibia with or without apical spur; abdomen robust; eye usually bare; head somewhat triangular (Fig 11G)……………………..………………..Tabanidae

Not as above………………………………………………………………….18

18. Wings usually with fewer than seven longitudinal veins (Fig1 2I).Cecidomyiidae

All veins equally heavy and more than 6-10 main veins………………………19

19. Wings with scales and cross vein at about the middle, antennae pilose type, long slender, hairy leg (Fig.12E, Fig. 13B) ……………………………...Culicidae

Wings without scale………………………………….....................................21

20. Housefly like (Fig.12G)……………………………………..……..…Muscidae

Wings somewhat like Housefly but R and Cu veins structure differ, row of fine hairs on the costal margin present (Fig 12D)……….…………Calliphoroidae

Wings covered with relatively long hairs, cross veins absent, 10-11 veins run to the margin (Fig.12C)….…………………………………………...Psychophidae

False margin………………………………………………………................21

21. Venation are sharply conspicuous and move more or less parallel with the border (Fig.12H)…………………………………………………….…Syrphidae

22. Wings with many fairly long hair attached along the veins ....Trichoptera

Abdomen is highly constricted (Fig. 11F), wings often with tiny hairs throughout membranes, stigma (dark spot on anterior part of front wing) often present on front wing………………..Hymenoptera……………………………………..23

Wings long and narrow, vein less or with only 1 or 2 veins and fringed with long hairs, minute insect (Fig.11C, E, Fig. 13C)……..Thysanoptera………Thripidae

Hymenoptera

23. Wing with large cells, recurrent vein, abdomen constricted …….Ichenomonidae

Legs show pollen- transporting apparatus (Fig. 13H)………………….Apidae

Orthoptera

24. Hind tibia with large spines at tip (Fig. 13M)…………………………Acrididae

Front femora with 2 or 3 apical spines, yellow brown wings, antenna Filiform (Fig.13G) ……………………………………………………Blattidae

25. Very less spines on dorsal surface of front tibia……………………Tettigonidae

Spines on one side of leg (Fig. 13N)…………………..………………Gryllidae

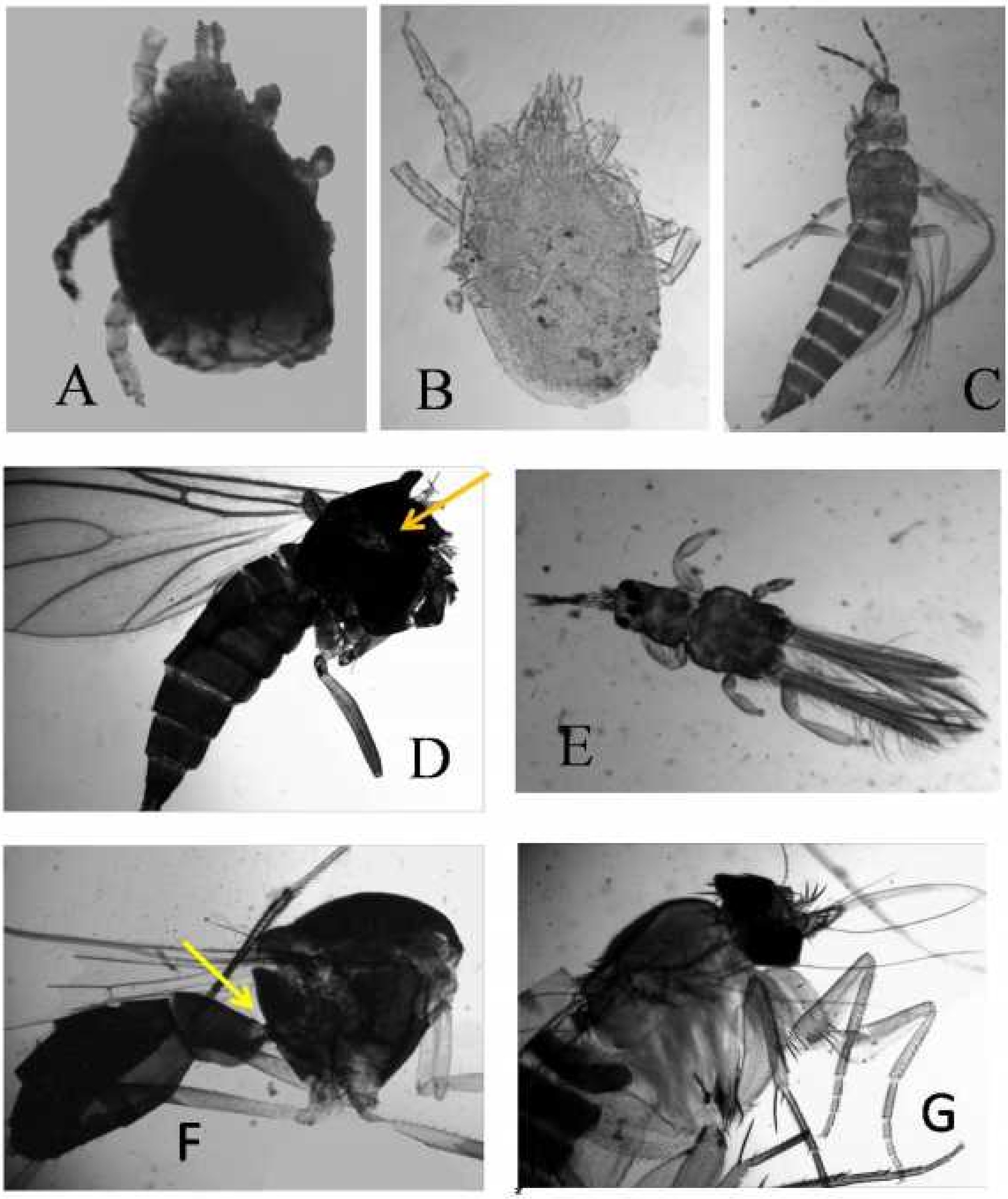

Figure 11 Insects and Mites found in bat dropppings. A, B. Mites, C,E. Thrip, D. Cecidomyiidae, F. Ichnimonide G. Tabanidae.

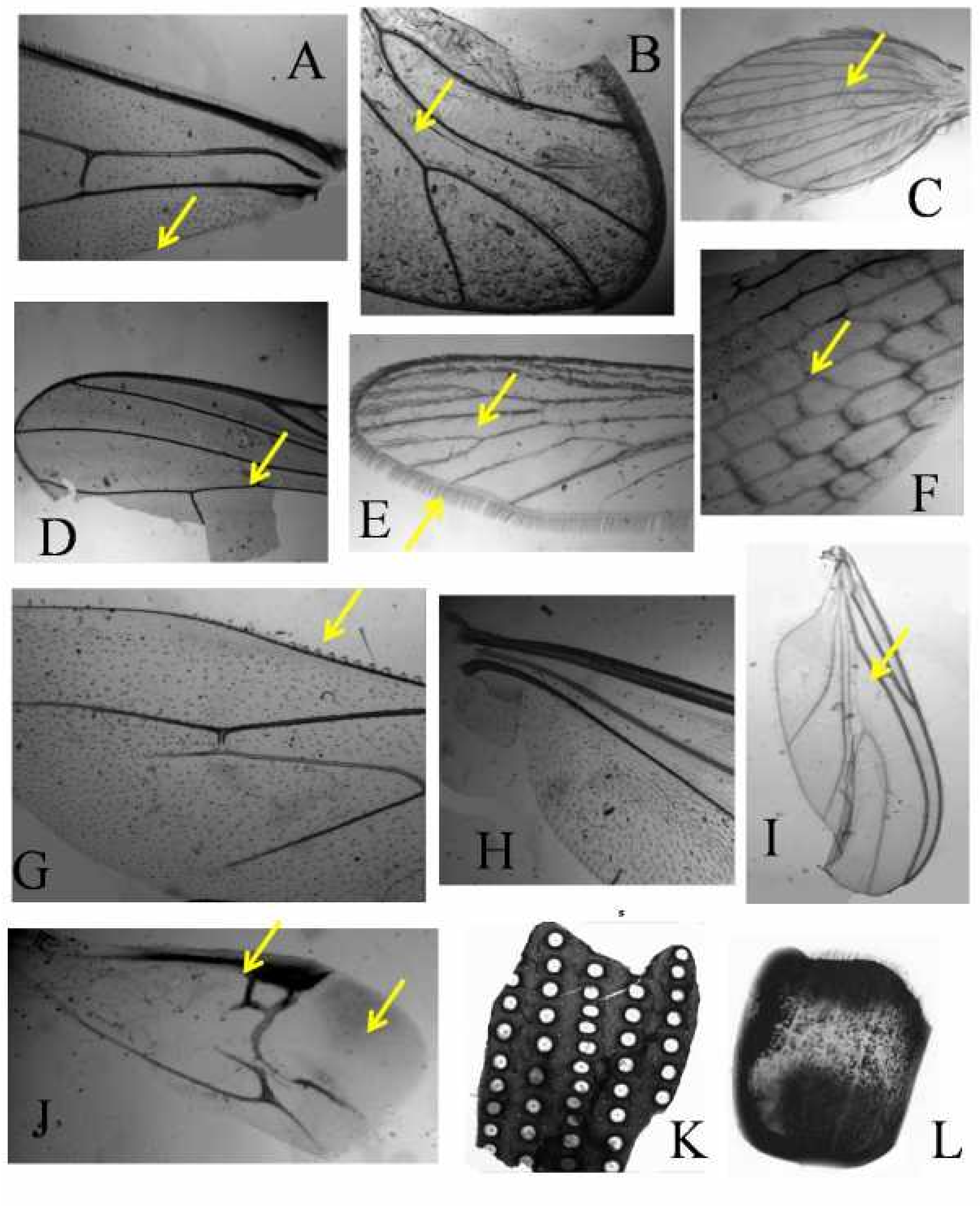

Figure 12: Wings of insects recovered from bat droppings. A. Diptera, B. Lepidoptera, C. Psychophidae, D. Calliphoridae, E. Culicidae, F. Odonata G. Muscidae, H. Syrphidae, I. Cecidomyiidae J. Miridae, K., L. Beetle (Coleoptera)

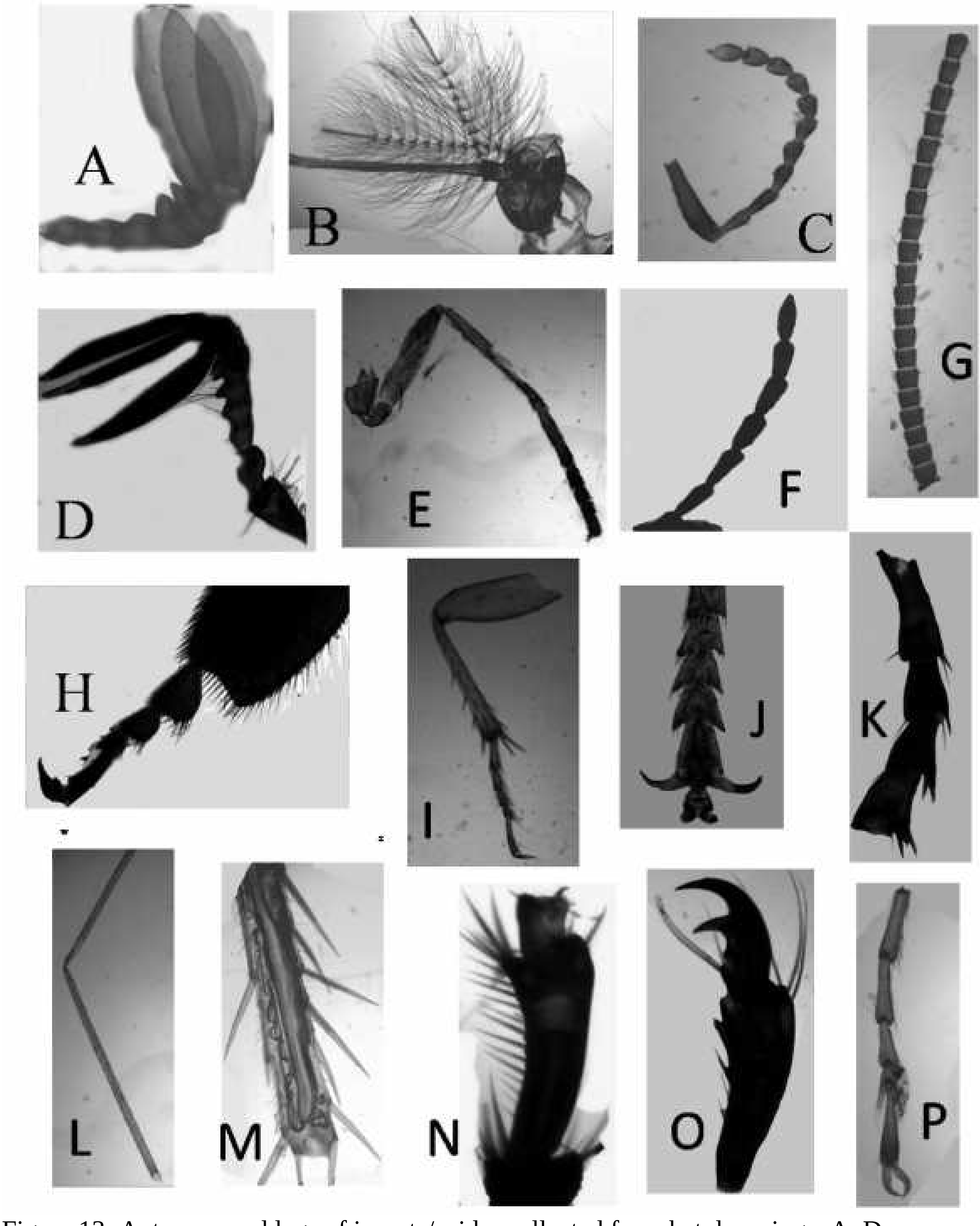

Figure 13: Antennae and legs of insects/spider collected from bat droppings. A, D. Antennae of Scarabaeidae, B. Antena and mouth parts of Culicidae, C. Antenna of Curculionidae, E. Leg of spider, F. Antennae of Trips (Thysanoptera), G. Filiform antenna of Cockroach (Blattidae), H. leg of Honey bee (Apidae), I. Leg of ground beetle (Carabidae), J, K, O, P. Tarsal segments of beetles (Coleoptera), L. Leg of mosquito (Culicidae), M, N. Leg of grasshoppers and crickets (Orthoptera).

5. DISCUSSION

5.1 Diet

The analysis of bat dropping is considered as reliable and conservation friendly technique to study feeding habits of insectivorous bats all over the world (Shiel et al. 1997). Whole or fragmented insect parts of different prey species have been widely reported in insectivorous bats droppings (Black 1974; Zhang et al. 2005) There is species- specific differences in diet lead to 'passive selection' of insect resources. Therefore, bats with different traits consume different resources, and 'passively' partition the resource.

Food habits analysis are also commonly expressed by percentage frequency; based on the number of animals in which food item occurred (Kunz 1974), percentage volume based on volumetric measurement or visual estimates (Whitaker et al. 1977). There are merits in using each approach, but it should be noted that different methods of estimating food habits (stomach contents vs fecal analysis; percentage volume vs percentage frequency) can lead to different interpreted e.g. a small prey item consumed in low numbers by most or all of the individual in a sample could be interpreted both as a high percentage frequency and low percentage volume. Ideally, food habits should be expressed both as percentage frequency and percentage volume. Another potential bias encountered in food habits analysis, from the feces, is that some individuals may cull parts before ingestion and lost characteristics necessary for identification and reliable enumeration (e.g. wings, elytra, head capsules). Additionally, differential digestion of whole or parts of insects could also bias the results; particularly when feces are used; soft-bodied insects may be partly or wholly digested and rendered unidentifiable. For e.g. Belwood and Fenton (1976) fed adult mayflies to *M. lucifugus* in captivity and found no recognizable remains in the feces, although Anthony and Kunz (1977) recovered legs and tarsi of mayflies from the feces of these same species taken in the wild. If such insects are eaten when they are only partly sclerotized, they could not be recognizable in the feces. So, many soft- bodied insects are found in less volume than hard insects and same in this study too.

The bats that find in both studied caves are *Rhinolophus* and *Hipposideros*, others (*Minipoterus* and *Megaderma*) are only guest visitors (Malla 2000). Dietary composition has been widely studied for many species of Rhinolophidae (Whitaker and Black 1976, Jones 1990, Wei et al. 2006). In these studies, Lepidoptera was the most dominant prey among all. Moths use the intensity of a bat's echolocation calls and the time between calls (Fullard 1987) to trigger their defensive behavior. By reducing the range at which a moth can hear its echolocation calls, a bat maximizes it's time to detect a prey and track its flight path. The allontonic frequency hypothesis recognizes the limits to a moth's hearing sensitivity allow bats to reduce the range at which they are detected (Fullard 1987). This hypothesis is appears to be fully supported by the data on the incidences of moths in the diets of Rhinolophidae and Hipposiderids (Jones 1992); but not in this study.

The result of the present investigation on dietary behavior of insectivorous bats provides strong evidence that bat species of Mahendra cave forages primarily on coleopteran followed by Orthoptera, Diptera and Hymenoptera. Thysanoptera, Hemiptera, Homoptera represented in only small quantities. This analysis is similar with many other authors who reported coleopteran as the main portion of diet in different bat species (Whitaker et al. 1994; Whitaker and Yom-Tov 2001; Lacki 2007).

Analysis of fecal droppings indicate that large, hard bodied insect such as carabidae, Scarabaeidae, Gryllidae, Blattidae were favoured intensively. Low percentage volume of Hemiptera, Homoptera, Thysanoptera showed that orders that comprises mostly small and soft bodied insects were not regularly prayed or may not found in droppings being soft which can be easily digested and in unidentified. On the other hand Coleoptera were reported to be the main or one of the main food items. This is not surprising because Coleoptera is the largest insect order in the world, comprising about a third of all insect species. However, the relative proportion of biomass of the various insect orders was not studied, thus it is not possible to determine the relationship between foods eaten and availability in each species, i.e. whether they take Coleoptera in proportion to their abundance or whether they actively select beetles.

Similarly, dietary investigation of insectivorous bats at Nagarjun cave showed that Diptera were taken greater in proportion than Coleoptera followed by Thysanoptera, Orthoptera and Hymenoptera. This difference in diet between two places can be affected by presence and absence of these insects in different seasons because of different practice and climate that alter the local or regional composition of the insect community. On the other hand the species of bats in two caves are also different, so they have different echolocation (Fullard 1987) call intensity to capture their prey.

Microchiroptera bats are specialized for echolocation, which involves broadcasting intense pulses of sound and receiving the much fainter echoes that returns from objects such as prey in their path (Bogdanowicz et al. 1999). They detect their prey by using echolocation over very short ranges of only a few meters (Kick 1982) as echoes reflected from insects are weak and atmospheric attenuation is severe at high frequencies (Griffin 1971). Echolocation call design affects prey detected in bats (Simmons et al. 1979) and variation in echolocation call frequency between closely related species may be related to resource partitioning by prey size (Barclay 1986).

Predictions about the insects eaten by bats also can be made from the morphology of teeth, jaws and cranina (Bogdanowicz, et al. 1999) inter- correlated the morphological factors and frequencies dominating the echolocation calls. Beetles eating bats are said to have thick jaws, well developed cranial crests and fewer but bigger teeth as compared with moth-eating bats, which have thinner jaws, less well -developed cranial crests and smaller teeth (Freeman 1979). The size of mandible ram is also an important prediction of the diet composition.

The presence of spiders and mites in the diet of bats indicates gleaning as a mode of feeding (Williams et al. 2010). In this study the presence of spider in low volume also indicate that bats of Najarjun cave are occasional gleaner or accidental encounters while flying through a cluttered forest environment around the cave environment. So, it mayn't be part of the diet. Spiders are nocturnal and construct webs of varying complexity located between foliage, veins of trees trunks within the environment. On the other hand Acari were also noted in the diet of bats of Nagarjun, it may because Acari is the parasite of others insects like Diptera, Coleoptera so it may presence in the study.

The result of the present dietary investigation also showed that the non flying diurnal insects such as Blattidae, Phasmidae and Curculionidae also form a part of diet in insectivorous bats of both caves. Hammer (1940), stated that such Dipterans and beetles remain active at cow pats for a short time after sunset and would still be at this time. Therefore, the presence of diurnal and non flying insects found in droppings analysis of bats of both caves implies that these bats glean these preys at least occasionally.

5.2 Spring-Autumn Diet Variation in Bats

As the climate change, the amount of food consumed by bats is also affected. Although the pattern of insect diversity is same the food items varies with change in locations. The Coleoptera and Diptera were highest food items in Spring and Autumn respectively in Mahendra cave which was similar with (Feldhamer 1995) though bat species was different. However Diptera and Thysanoptera comprised highest amount of food items in spring and autumn respectively in Nagarjun cave while Malla (2000) found Coleoptera and Lepidoptera as dominant species of Nagarjun in September and March respectively but the insect order variation was same with that study. Thysanoptera was found only in Autum of both caves because in Autumn, Thysanoptera search warm places so may be found in caves. In spring high percentage of hymenoptera was found in both caves as (Malla 2000). During autumn, when flying insects are assumed to be less readily available, the order Homoptera, Thysanoptera, Hemiptera constituted a relatively larger part of the diet. It indicates that bats of both caves are opportunistic forager which helps them to sustain during colder months too.

5.3 Relation of Food Items

Neuza et al. (2009) found that no single environmental factor, except the temperature play a key role in regulating the insect abundance. But the sub- tropical, warm country likes ours the abundance of insect is throughout the year. This may be due to the mild day temperature, although the cool night-time temperature causes a decline in nocturnal insect activity during cold days. Lepidoptera and Orthoptera showed highest similarity in their seasonal abundance pattern followed by Coleoptera and Hymenoptera (Neuza et al. 2009). In this study also there is no significant difference in the consumption of Orthoptera, Coleoptera and Diptera so the null hypothesis for t-test was accepted in both caves but in case of Hymenoptera there is significant difference. On the other hand, in both caves Rhinilophidae bats are found which feeds regularly throughout the year, although the foraging range of this bat in cold is reduced by approximately 50% to the summer range (Williams et al. 2001). Present study shows there was less number of insects in autumn than in spring, however, the mean value of consumption was similar in both seasons. According to t- test result the consumption of insect between two caves was also similar because the temperature difference between two places where the caves lied was also similar which was signified by the data of two places placed in study area.

6. CONCLUSION

The diet analysis of bats in Mahendra cave and Nagarjun cave represents that the insectivorous bats were found in both caves. The diversity of food items included 10 insect orders in addition to spider and mites. Although the diversity pattern of insect food items in both caves similar but the variety of insect food varies with changing geographical locations of two caves. Similarly there was a variation of insect availability in Spring and Autumn season which is general pattern in insect life due to seasonal changes in weather conditions particularly temperature.

7. RECOMMENDATION

Based on the limited study area and time frame, following recommendations have been made;

- Further research in wide geographical location and all season can provide the actual Figure of insectivorous bats in Nepal
- Different bat species consume different insects so species specific food habit analysis is recommended for future work.
- Bats consume pest species of agriculture; the quantification of such data will generate bat conservation for agricultural productivity.

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9. APPENDIX

9.1 Bat species found in the two study areas

Rhinolophus pusillus Temminck, 1834

They are widely distributed in South Asia, Southern and South-western China and much of Southeast Asia having tropical and temperate climate. In Nepal they are recorded from Central and western region (Molur et al. 2002). This species roosts in small or large caves in hilly areas and houses. They have leaf like, horseshoe-shaped protuberance on their noses. They emit echolocation calls through this structure, which may serve to focus the sound. Hind limbs are not well developed, so they can't walk on all fours; conversely wings are broad, with rounded ends having fluttering like flight. Being short tail they can't form large enough pouch for holding insects. When large insect is caught in flight, it may be tucked into wing membrane under the arch while bat manipulates it with its mouth. The females have a pair o mammary glands and two "false nipple" above and to the side of the genital opening, to which newborn bats cling for a few days after birth. It occurs co-occurring with others*; R. affinis, R. luctus, R. macrotis and others species; H. armiger, H. cineraceus, Myotis nipalensis* (Csorba et al. 1999; Ghimire et al.2010; Thapa et al.2010).

They are insectivorous, usually hunt within 6 m of the ground and will also feed on the ground.

Rhinolophus ferrumenquinum (Scherber, 1774)

This species has noseleaf like that in *Rhinolophus affinis* with horseshoe relatively narrower, not covering whole muzzle. The lancet is narrowly pointed with concave sides. Drosal pelage is long, soft and dense varying from uniform light grayish to drab brown with paler hair bases. Ventral pelage is pale grayish brown. Immature specimens are greyer than adults. It is gregarious and roost in caves, old and ruined houses and buildings. It roosts solitary, in small to large colonies and co-occur with other species such as *R. pusillus, R. affinis, R. sinicus* and others *Myotis nipalensis* and *H. armiger*. It feeds on small insects; lacewings, small moths, spiders and grasshoppers.

Rhinolophus affinis Horsfield, 1823

It is known as Intermediate Horseshoe bat which is widely distributed throughout of South Asia, Southern and Central China and Southeast Asia. It has a very distinctive noseleaf that extends to cover much of the face. The edges of the noseleaf are grayish-brown, but the inner parts appear slightly pink. The connecting process is rounded. The fur on the back and head is a light brown, sometimes with a bit of a reddish tinge to it, and the fur on the underside is a bit paler.

Ears are large and brown and like all *Rhinolophus* there is no tragus, but there is a very pronounced antitargus. The wings are a dark brown and are quite broad and rounded so that the bat is maneuvrable enough to fly on the dense forest. Small tail membrane stretches between the legs but does not go much beyond the ankle. The tail itself is fully enclosed by the membrane, with may be just a mm or two of the poking out beyond the edge. At each ankle, there is a small rod of cartilage called a calcer, to which the tail membrane is attached, which helps the bat control the position of the membrane in flight. This is mainly the forest species, found in both primary and secondary forest at all elevations. It roosts in large numbers in limestone caves associated with other species*; Rhinolophus, Hipposideros, Myotis*.

It is known as Greater Horseshoe bat. Its distribution covers Europe, Africa, South Asia, China, Korea, Japan and Australia. Bat lives in warmer region of areas of open trees and scrub, near areas of standing water (ponds), areas of limestone and human settlement. They are faithful to their summer and winter roosts, returning to the same sites each year. Bat is an average between 57 and 71mm long with a 35-43mm tall and 350-400mm wingspan. The fur of the species is soft and fluffy ,with the base of hairs being light grey ,the dorsal side hair grey brown and ventral side grey white, with juvenile bats having more of an ash grey tin to their fur. Wing membranes and ears are light grey-brown. It weights up to 30gm. During the winter the bats hibernate in caves, underground places or abandoned. They are insectivorous which usually feed on small insects; lacewing, small moth, spiders and grasshopper.

Hipposideros armiger (Hodgson,1835)

It is the Hipposiderid bat. Noseleaf of bat has from supplementary leaflets, with the outerleaf distinctly smaller than the other three. Intermediate leaf has a well developed median process and has numerous vibrissae and the upper surface is "wave-shaped" with at least four convexities. Behind their posterior leaf above each eye there is a fleshy elevation. Tufts of black hairs project out from frontal depression in both sexes. Posterior concavity of pinna is serrated (Thapa et al. 2009). In Nepal they are found commonly in cave. In cave some were roost in moist places while some were in dry places. These species is the first to fly out of the cave and may have poor echolocation. They are low flying species and breeds once a year (Bates and Harrison 1997). They roost in colony of few individuals to hundred. Its colony can co-occur with colonies of other species such as *Rhinilophus*, *Myotis* and *Miniopterus* etc.

Megaderma lyra lyra È Geoffroy, 1810

This is a large bat with a rather ugly appearance due to its big head with prominent muzzle. Pinna is the characteristic and oval shaped, large with fringe of white hairs on inner margin, forehead and upper cheeks of the face is hairy. Snout is naked and flesh coloured. Noseleaf is erect straight and about 10mm in height. The wings are rather broad due to the last digit being relatively long. Such a design probably result in a slower but most controlled type of flight which is adapted to their method of hanging. Usually hind feet are comparatively larger in this species and further peculiar feature is in the development of the first digit which consists of only two joints whilst the remaining digits have true joints.

It inhabits the dry as well as humid areas with agriculture fields and wetlands. It can roost solitarily and in small to large colonies ranging up to several hundred individuals. It has been roasting in caves, old buildings, thatched huts etc. The bat is predacious, carnivorous and commonly known as false vampire bat. When it is full dark it emerges for hunting or search the prey in ground. It has a very characteristic habit of carrying its prey, one secured to favour perching sites, where the mean can be devoured at leisure. They feed upon varieties of insects, however vary seasonally also small vertebrates (frogs, reptiles, rodents) (Csorba et al. 1999). This bat is active throughout the year and does not hibernate but probably makes seasonal migration (Shrestha 1997). They groom own self and to each other, shakes its mouth and face while resting (Thapa 2009).

Miniopterus schreibersii fulignosus (Kuhl, 1817)

This is one of the commonest bats of Central Nepal and commonly known as 'Schreiber's long-fingered bat' (Shrestha 1997). The size of the bat is medium. Each wing has highly developed second phalanx of the third digit. Pinna is small and broad; the height is slightly curved forward. Short hairs of the forehead extend to the nostril pads cheeks are naked below the eyes. Membranes are uniformly dark throughout. It is Gregarious often found roosting in colonies in crevices or creeks on roofs, rafters and in holes in ceilings. It colonies can occur with colonies of other *Rhinolophus, Hipposiders, Myotis*. It is known to feed on ant, Diptera, Coleoptera (Bates and Harrison 1997) and hibernate in the Himalayan foothills (Shrestha 1997). Its flight is fast (Ghimire et al. 2010). They are canopy fliers to catch the insect but adopt low flight above the stream and water surfaces.

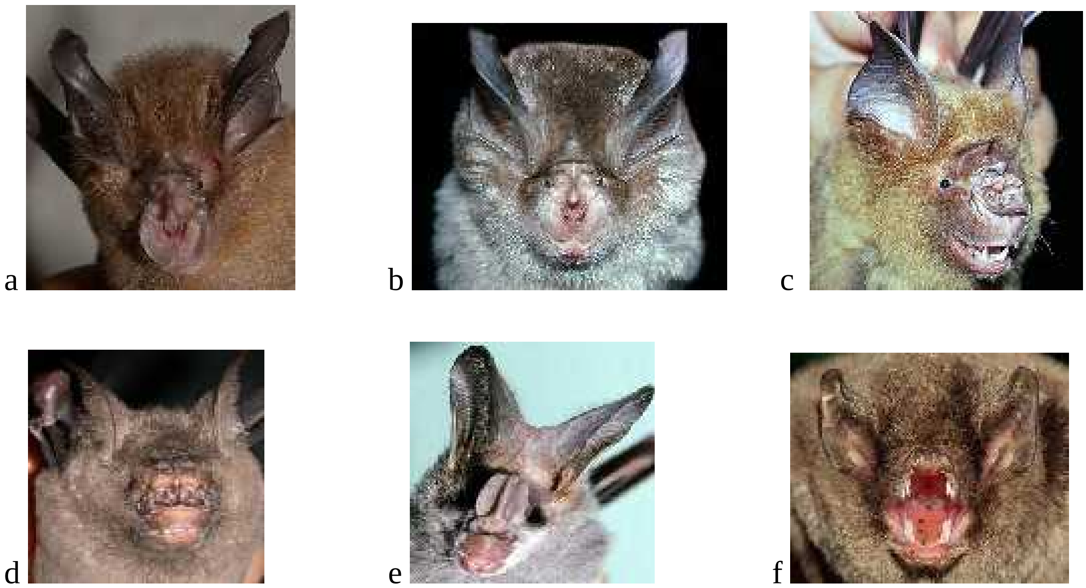


Figure 14: Bat species in the Study Caves

a) *Rhinolophus pusillus*, b) *R. ferrumenquinum*, c) *R. affinis*, d) *Hipposideros armiger* e) *Megaderma lyra* and f) *Miniopterus schreibersii*

9.2 Structure of Insects and Insect Parts used for identification

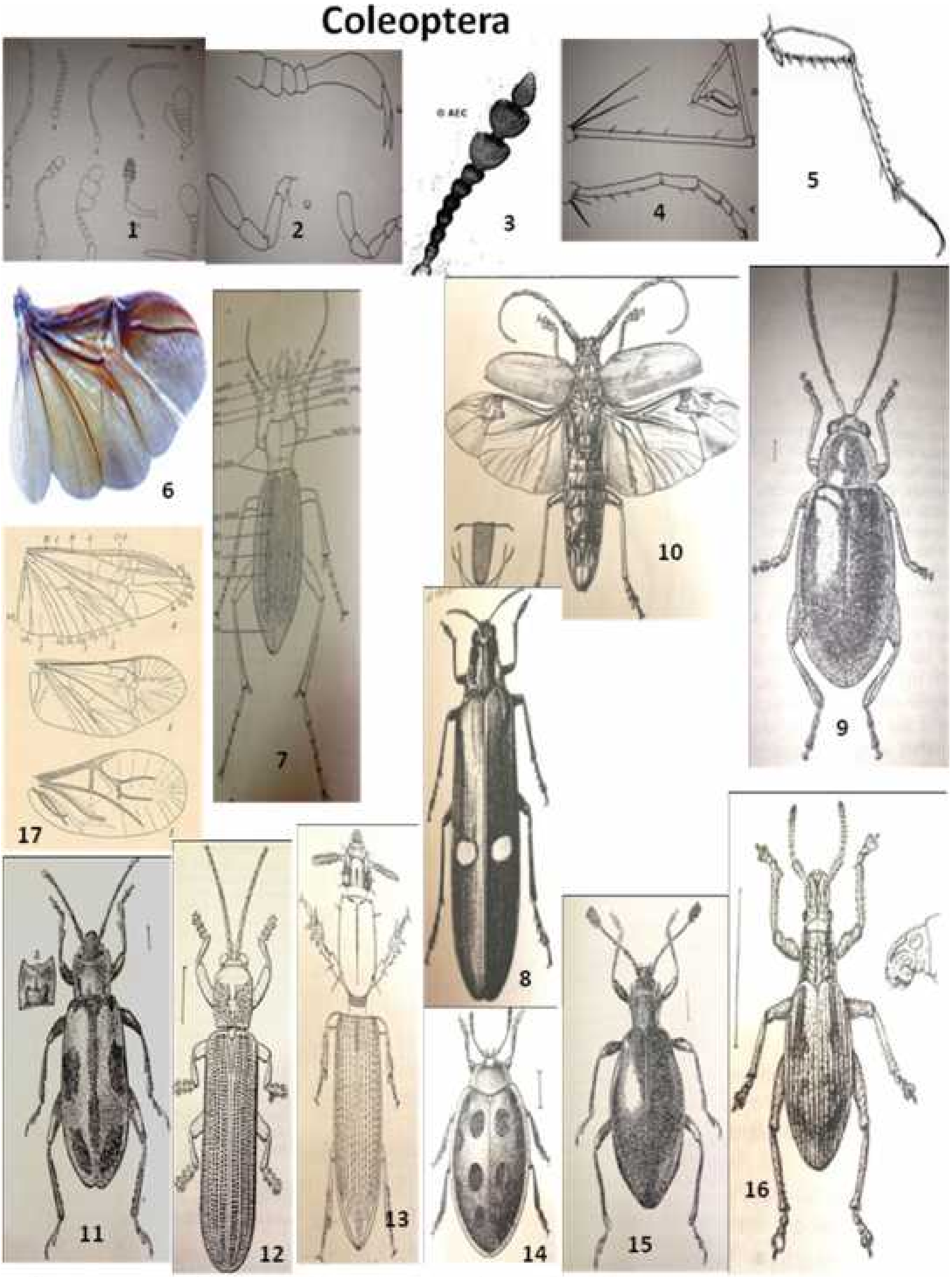


Fig: 1) antennae of scrabadiedae, 2) antenna of cerambacidae, 3) antennae, 4) leg, 5)leg, 6)wings, 7)carabus,8)cataxantha, 9)aphthona 100 batocera, 11) ancylopus, 12) Anisoderopsis, 13) clivina, 14) cyclotoma 15) encymon 16)episomus, 17) wings

Figure 15: Coleoptera (i)

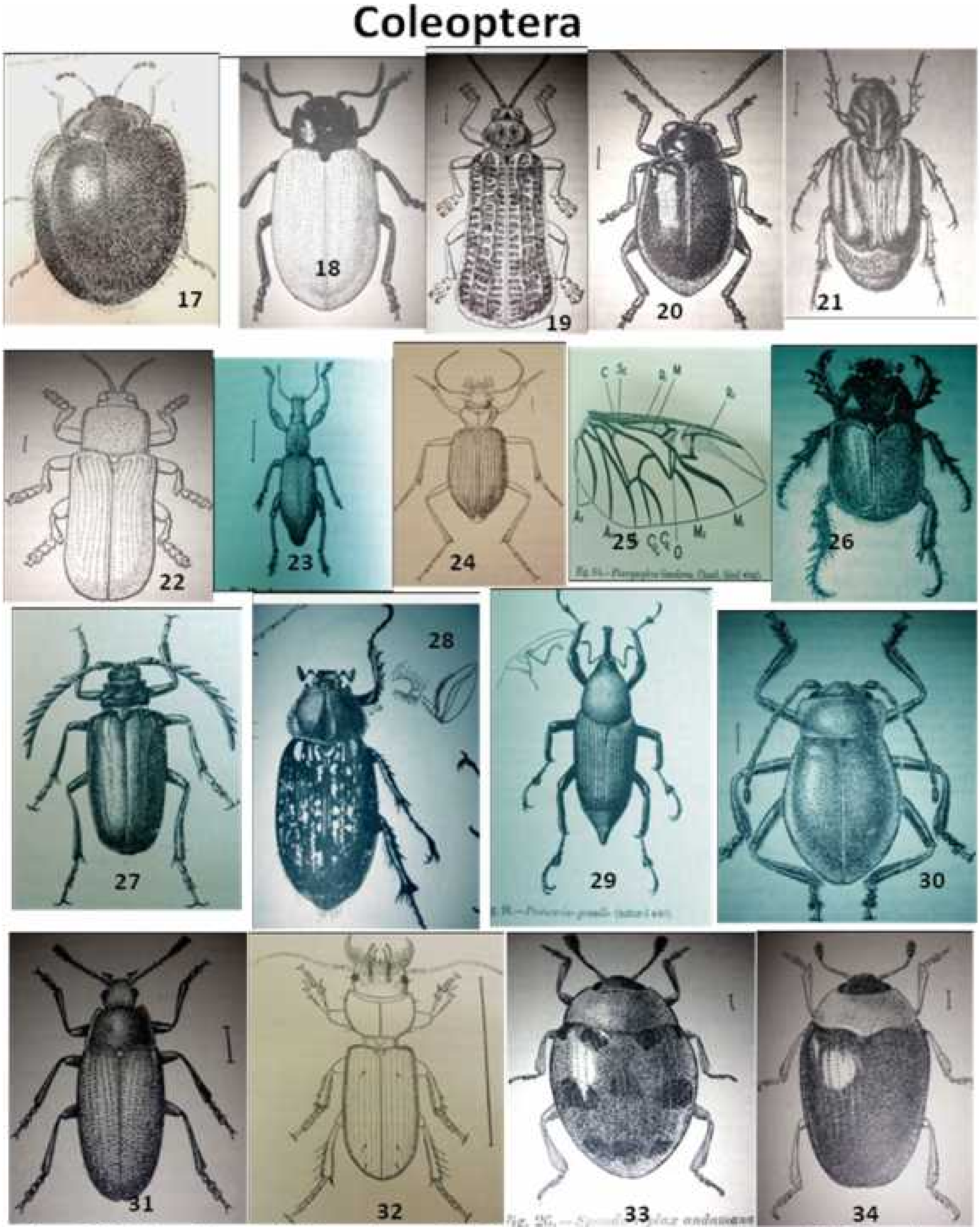


Fig 17)Endocoelus, 18)Eumela, 19)Gonophora, 20)Haltica, 21)Idiovalgus
22)Leptispa
23)Leptomias, 24)Nebria, 25)Pheropsophus, 26)Phyllognathus, 27)Priouus, 2
8)Propomarcus, 29)Protocerius, 30)Pseudolina, 31)Rhodotritoma, 32)Scarites,
33) Spondotriplax, 34)Tritoma

Figure 16: Coleoptera (ii)

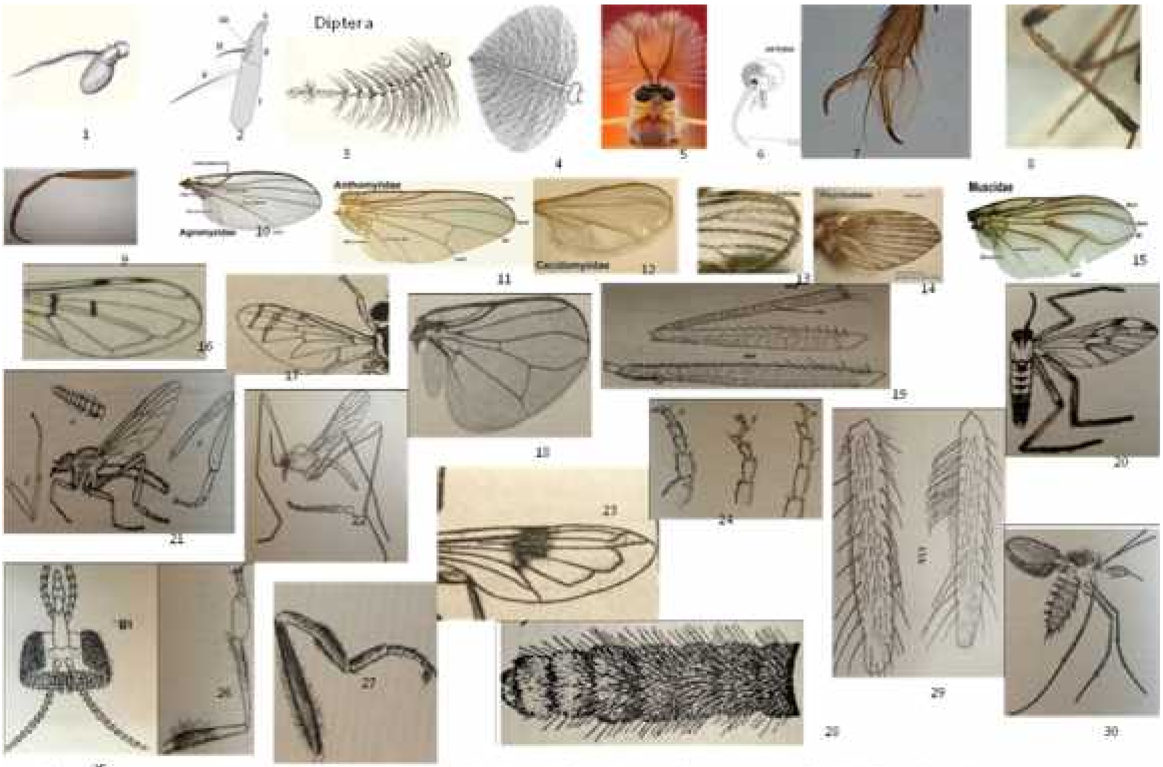


Fig: 1,2) Aristate antenna, 3,4,5) Antenna of culicidae, 6)head of musca, 7,8,9) legs of Diptera , 10) Agromyzidae, 11) Anthromyzidae, 12)Cecidomyzidae, 13) Culicidae, 14)Psychodidae,
15) Muscidae, 16)Bacsha, 17) Graptomyza, 18) Lyperosia, 19)Stomoys, 20) Rhyphus 21)Babio, 22) gymnastes, 23) wing, 24)Simulidae legs 25)head of Musca, 26)Platychirus, 27)Eristalis
28)Body of Annopheles, 29) Helina, 30) Phlebotomus

Figure 17: Diptera

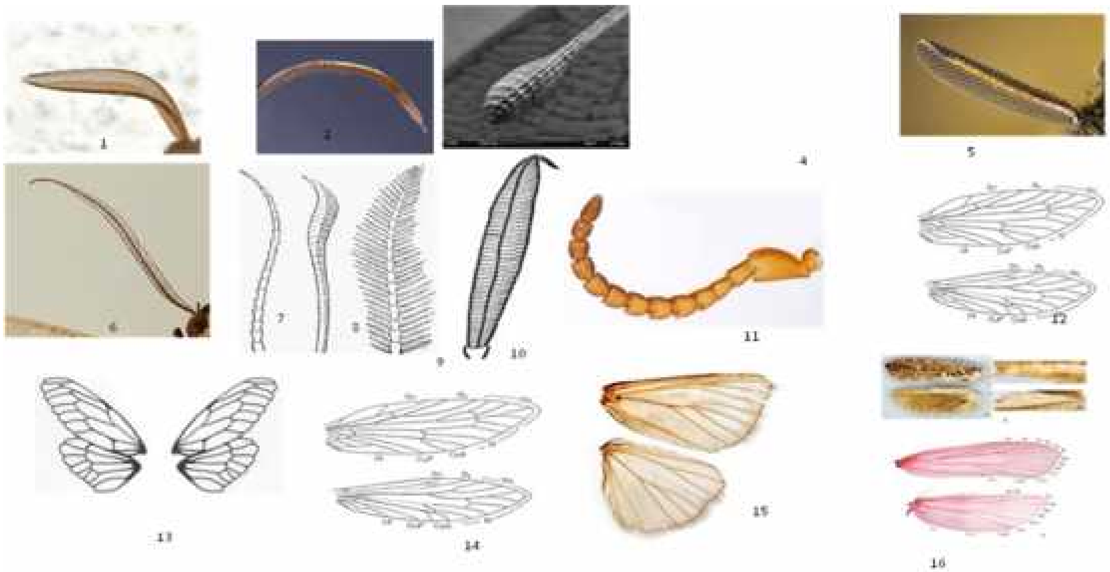


Fig1,2, 3, 4, 5, 6 antennae Lepidoptera, 7 Noctuidae, 8 Sphingidae 9 Saturnidae, 10 Moth antenna, 12, 14 Microlepidoptera, 13 Pieridae, 15 Saturnidae
16 wing of different butterfly

Figure 18: Lepidoptera

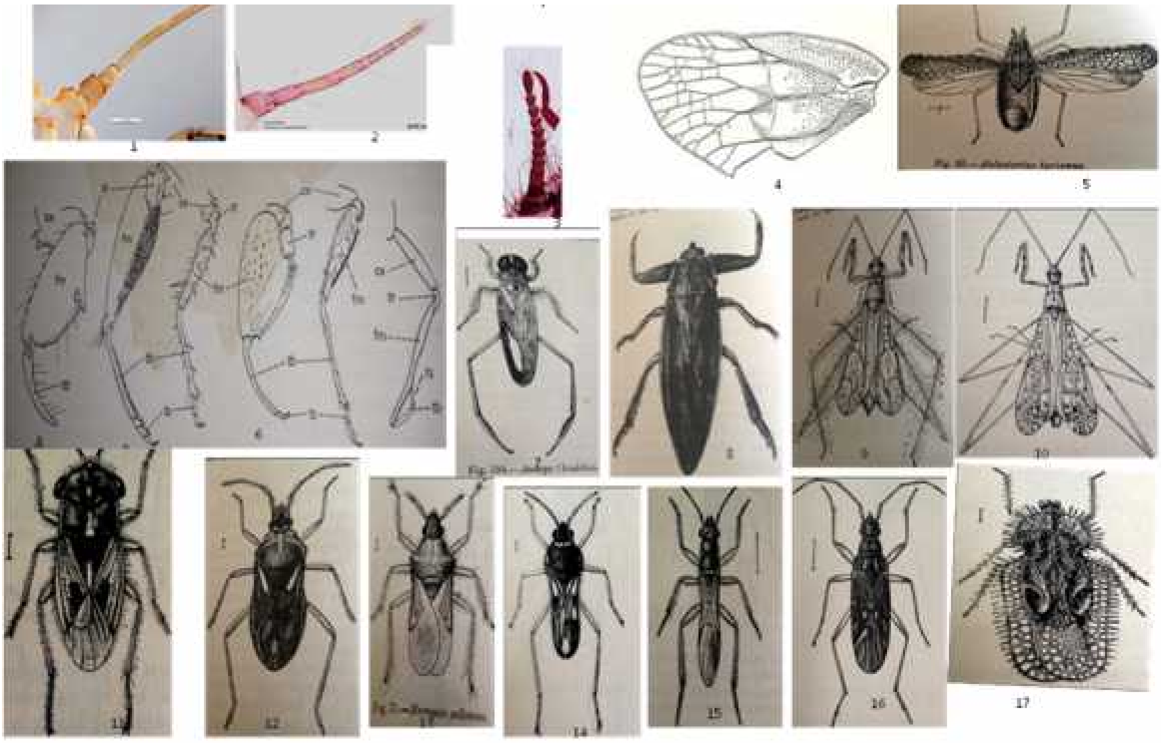


Fig1, 2, 3 antenna , 4 wing, 5 Abdastartus, 6 Phymitidae, Belostomatidae, Reduviidae, Naucoridae, Nabidae, Nepidae 7 Anisops, 8 Belostoma 9 Calphurnia 10 Calphurnia 11 Geocoris 12 Hebrus
13 Nerthus 14 Microvelia, 15 Merragata, 16 Pamerana, 17 Geocoris

Figure 19: Hemiptera

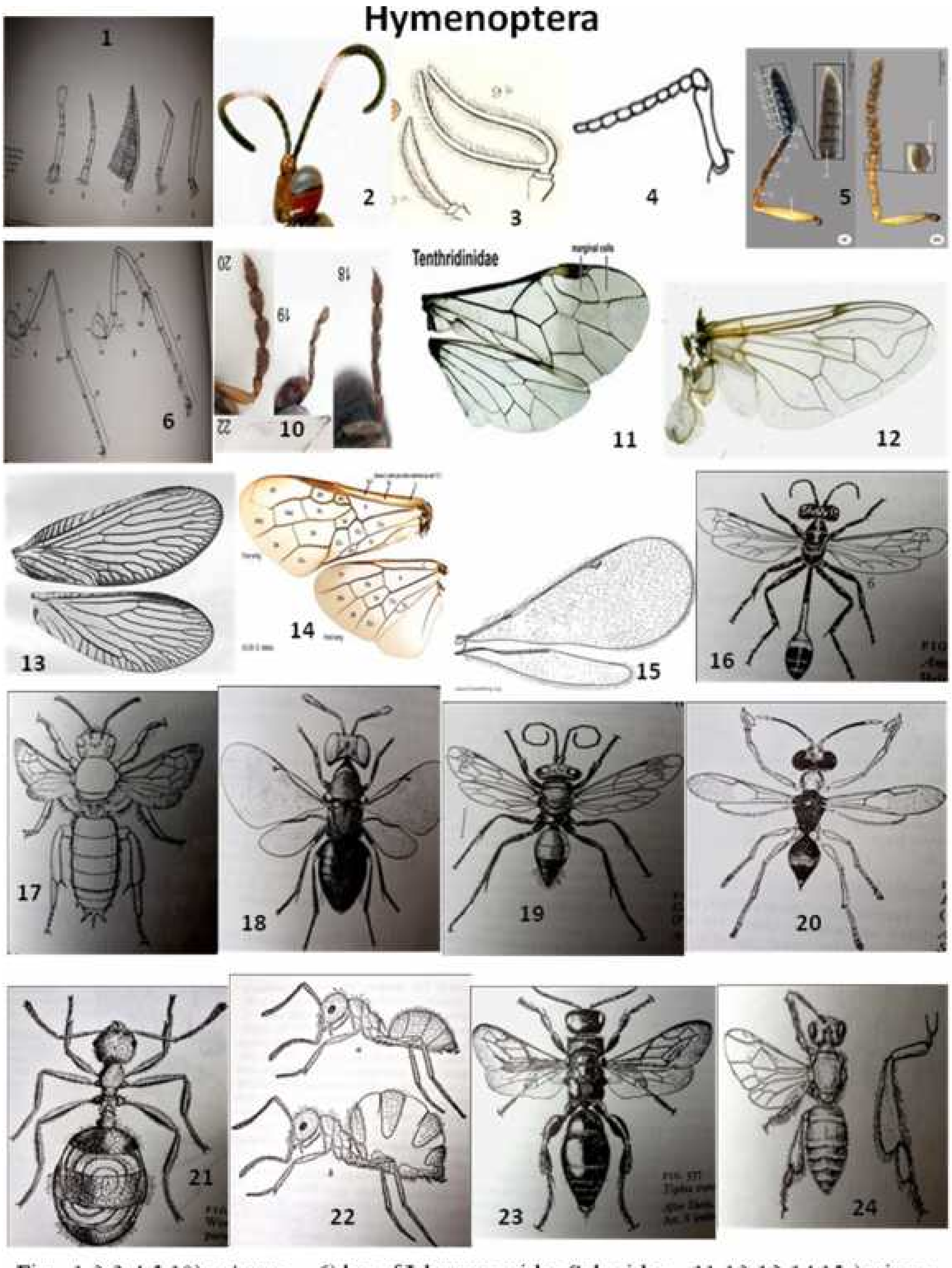
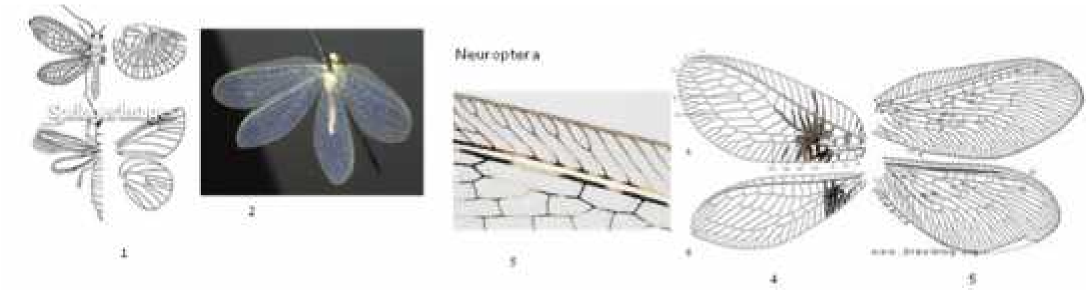


Fig: 1,2,3,4,5,10) antenna 6) leg of Ichneumonidae,Sphecidae 11,12,13,14,15,) wings 16) Ammophila 17) Anthidium 18) Cerceis 19) Chrysis 20) Ecgthrodolphax 21) Pheidole 22)Prenolepsis 23)Triphia 24)Trigona

Figure 20: Hymenoptera



Fig; 1,2,3,4,5 wings of Neuroptera

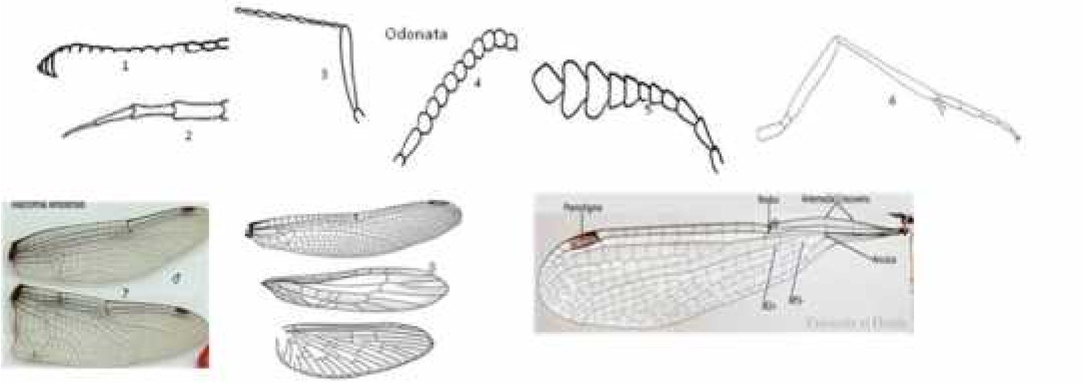


Fig 1,2,3,4,5) antenna of odonata 7) wing of Sympterum 8) wing of Damselflies 9)wing of Dragonfly, 6) leg of Dragonfly

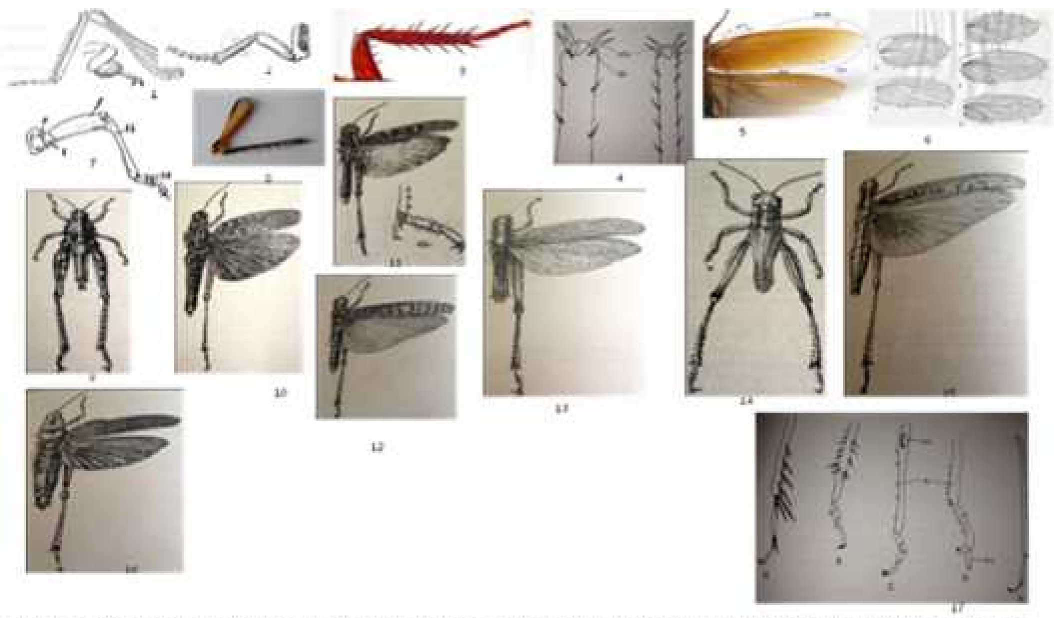


Fig 1)leg of Tetrigidae 2)leg of Tettigoniidae 3)leg of Blattidae 4)leg of Acrididae 5,6) wing of Blattidae 7)leg of Mantidae 8) leg of Gryllidae 9)Alectorolophus 10)Aularches 11)Heteropternis
12)Schistocera 13)Orthacanthacris 14)Hieroglyphus 15) Ortiacanthacris 16) Pacilccerus 17) leg of Gryllidae, Blatidae, Tettigoniidae, Aciridae, Gryllidae

Figure 21: Orthoptera

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LIST OF FIGURES

LIST OF ABBREVIATIONS

C^o	Centigrade
CCINSA	Chiroptera Conservation and Information Network of South Asia
m.a.sl	Meter above sea level
mm	Millimeter
SMCRF	Small Mammal Conservation and Research Foundation
UNEP	United Nations Environment Programme