
The Corbett Foundation
Some Insects & Spiders of Kanha Tiger Reserve
by Aniruddha Dhamorikar
The Corbett Foundation
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Spiders
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Study of some Insect orders (Insecta) and Spiders (Arachnida: Araneae) of Kanha Tiger Reserve

by

The Corbett Foundation

Project investigator
Aniruddha Dhamorikar

Expert advisors
Kedar Gore
Dr Amol Patwardhan
Dr Ashish Tiple

Declaration

This report is submitted in the fulfillment of the project initiated by The Corbett Foundation under the permission received from the PCCF (Wildlife), Madhya Pradesh, Bhopal, communication code क्रमांक / तकनीकी-I / 386 dated January 20, 2014.

Kanha Office
Village Baherakhar, P.O. Nikkum
Dist Balaghat,
Madhya Pradesh 481116
Tel.: +91 7636290300
info@corbettfoundation.org

Admin office
81-88, Atlanta, 8th Floor, 209,
Nariman Point, Mumbai,
Maharashtra 400021
Tel.: +91 22 614666400
www.corbettfoundation.org

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Aniruddha Dhamorikar

Image credits (used under Creative Commons):

Amol Patwardhan: Mottled emigrant (*plate 1.l*)
Dinesh Valke: Whirligig beetle (*plate 10.h*)
Jeffrey W. Lotz: Kerria lacca (*plate 14.o*)
Piotr Naskrecki, Bud bug (*plate 17.e*)
Beatriz Moisset: Sweat bee (*plate 26.h*)
Lindsay Condon: Mole cricket (*plate 28.l*)
Ashish Tiple: Common hooktail (*plate 29.d*)
Ashish Tiple: Common clubtail (*plate 29.e*)
Aleksandr: Lacewing larva (*plate 34.c*)
Jeff Holman: Flea (*plate 35.j*)
Kosta Mumcuoglu: Louse (*plate 35.m*)
Erturac: Flea (*plate 35.n*)

Cover: *Amyciaea forticeps* preying on *Oecophylla smargdina*, with a kleptoparasitic Phorid fly sharing in the meal.

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Much of the credit of this work goes to the experts and taxonomists whose undaunting task is to christen the denizens we share the world with – in particular I thank Dr. Amol Patwardhan and Dr. Ashish Tiple for helping with identifications and in providing guidance in writing this report, especially concerning Coleoptera and Odonata. My sincere gratitude to the taxonomists who went out of the way to help me narrow down on the species in question based solely on photographs.

This study is the result of the continuous support and guidance of The Corbett Foundation; I thank the management for their continuous support in bringing the lesser known animals and plants in the forefront of mainstream wildlife sciences.

This report-cum-book is dedicated to all the taxonomists and ecologists who have worked in the central Indian landscape, and whose works are immortal in understanding the rich biodiversity and the ecology of this region.

Contents

Executive Summary

The diversity of an ecosystem determines its complexity in the form of several overlapping interlinkages – and the integrity of these interlinkages determines its resilience. One of the key factors why complex ecosystems function so efficiently with minimum loss of energy and maximum utilization of resources is its highly versatile, highly evolved residents – insects and spiders.

This report-cum-book serves two basic purposes: to compile scattered knowledge about Kanha's insects and spiders, and to present them to the managers, residents, and visitors. It offers a detailed account of the study undertaken on insects and spiders of Kanha Tiger Reserve's iconic forests and grasslands. We set out to answer the most fundamental question: how many of them really are there in Kanha? From the smallest flying insect, a wasp, to one of the largest insects, the Giant Water Bug, Kanha is home to an array of these six and eight-legged creatures. Although we set to answer this fundamental question, upon which other work can be developed, we became lost in the sheer diversity of insects and spiders, and their diverse roles in Kanha's ecosystems. Based on the current study, we estimate the diversity of this group of animals to be more than 2000 species. This study is our humble effort to document the most common of all in a period of one year – and we have managed to touch only the tip of Kanha's diversity iceberg, the rest remains as elusive as the tiger.

One of Kanha's largest insects: the Giant Water Bug, in comparison to one of the smallest: a Chalcid wasp

There are several extensive works done in the past focusing on some group of invertebrates, such as butterflies, moths, termites, dragonflies and damselflies; however they've never been accessible to those interested in the other life of Kanha. This book offers an entry into the world of animals that live at the foot of the charismatic vertebrates, but also fly as high as the eagles.

A total of 550 individual specimens, most identified upto Family, Genus, or Species-level, are documented in this book. 436 of which are insects belonging to 21 orders; and 114 are spiders belonging to one order. It also glances at the 9 non-insect terrestrial arthropod orders, and 4 non-spider arachnid orders.

The most common social insects of Kanha are ants, followed by termites and honeybees. The most common solitary insect is the cricket, followed by moths and butterflies, beetles, true bugs, bees and wasps, cockroaches, true flies, and dragonflies and damselflies. The most common spiders of Kanha are lynx spiders, followed by wolf spiders, jumping spiders, orbweavers, crab spiders, and comb footed spiders.

We observed that forest type plays a significant role in determining the ecology and community structure of insect and spider assemblages especially during harsher seasons, such as summer. Owing to Kanha's varied vegetation type, a general trend of diversity and density was observed. Sal forests were the most diverse and dense in terms of insects and spiders, followed by mixed deciduous forests, bamboo dominant forests, and grasslands. As stated earlier, this trend is probably typical of summer – the harshest season of the region – where niche availability is lesser, resources are scantier, and temperatures higher.

The ecology of the insects and spiders documented portray an interesting ratio of ecosystem services they provide: 47% help in biological control either through predation or parasitism; 30% help in pollination; 9% in biodegradation; and 13% are pestiferious in nature – either damaging crops, affecting health, or are a nuisance. 1% is utilized by local communities for commercial purposes, such as honey collection.

The study also puts forth some recommendations on scientific monitoring, exploring indigenous biological control agents, inventorizing ecosystem services, exploring insect-based habitat restoration programmes, and developing a butterfly garden for increased awareness amongst Kanha's residents and visitors.

1. Preface

Arthropods are considered to be one of the most primitive forms of life that exist today, and are undeniably the most successful on our planet. More than half of all life on Earth comprises of arthropods, and a large part of it is dominated by insects and spiders, with scientists predicting about 5 million species of insects alone, closely followed by Arachnids (Mora *et al* 2011). This diversity, a result of various abiotic and biotic interactions, has given rise to myriad forms of functions extremely vital for the Earth's ecosystem. They constitute an important food resource; act as predators, parasites, and disease vectors for many organisms, including humans (Schowalter 2011). Perhaps their most recognised roles in ecological functioning are pollination, decomposition, and the ability to control the populations of pestiferous organisms. According to Losey and Vaughan (2006), these ecosystem services amount to $60 billion a year in United States, and over $171 billion worldwide for pollination alone (TEEB 2010).

Although the role of insects and spiders is recognised for its benefits, and loss, to human resources, their ecological roles that span from micro-habitats to landscapes are less understood, partly because of the complexities involved in addressing the taxonomic, temporal, and spatial dynamics collaboratively (Schowalter 2011). To understand the role insects and spiders play in an ecosystem, a comprehensive biodiversity assessment is required of organisms that depend upon insects and spiders (eg. insectivorous birds and mammals), as well as those getting impacted by them (eg. pollination by insects, pest control by spiders).

In India, more than 53,400 species of insects (Alfred *et al* 1998) and over 1686 species of spiders (Keswani *et al* 2012) have been documented so far, with the number of species being discovered increasing every year since. In the context of Kanha Tiger Reserve (KTR), a comprehensive assessment has not been undertaken to ascertain the role of these invertebrates in the basic functioning of KTR's ecosystems which is reined by apex predators such as tigers, leopards, and other carnivores. This study was therefore undertaken to act as a primer to document the insect and spider diversity of KTR, and to understand the ecological role they play. This study however is incomplete, but it opens a new chapter of KTR's most diverse group of fauna – insects, and their counterparts, the spiders.

2. About this report

The most common question asked while counting or photographing insects and spiders was, why document them? They have existed, and will continue to exist, in this landscape for thousands of years. The answer to that question is not only complicated, but without concrete proof of their importance in the ecosystem – and this becomes the major reason why documenting these invertebrates is important. Their value will not be understood unless we understand them and their ecology. With this objective in mind, this report focuses on the diversity and the ecology of insects and spiders recorded in KTR.

To make this report, on-field photography was employed to document the diversity as it exists on the field, and photographs are relied upon heavily for better understanding of the insect and spider diversity.

For the ease of the reader, it has been divided into five sections; sections I and II focus on insect and spider diversity and density, respectively. Each of these sections is further divided according to the modern system of classification, and to simplify the report, only focuses on Order, Family, Subfamily, Genus and Species (in that order). Each species has a picture plate associated with it, as has been explained in *2.1 Key to images*.

Section III discusses in detail the ecological role played by the documented diversity, and is further subdivided into chapters that enlists them according to their roles, viz. pollinators, herbivores, detritivores, parasites and predators, and pestiferous, along with a list of vertebrate fauna dependent on them.

Section IV focuses opens a discussion through recommendations on scientific and education concerning this group of organisms, and section V provides an index of organisms documented, and bibliography of studies undertaken in this region.

The report has been fashioned as a report-cum-field guide and reference book. The main reason of designing this report in this way is for it to be easily accessible to the user without the hassle of scientific jargon.

2.2 Key to images and text

A sample image below provides the key for the image plates.

1 = Plate number
h = Image number

Text on the adjoining page provides the following details:

1.h. Common Jezebel; *Delias eucharis*;; Pieridae: C Seen in all vegetation types, mostly in fields of Raddish and Carrots.

Naming scheme used:

Common Jezebel = Common name of the insect.

Delias eucharis = Scientific name of Common Jezebel. *Delias* is the generic name (genus), *eucharis* is the specific name (species).

Pieridae = Name of the Family it belongs to.

sp. = stands for "species"; it is mentioned only when the genus is known and species is unknown.

cf = stands for "confer"; used between genus and species name or before genus name when the actual specific identification is unsure, but is closely related to the genus/species name mentioned. Eg. *Delias* cf. *eucharis* or cf *Delias* sp.

Delias? : A question mark is used after genus name or Family name when the identification is uncertain.

C = Common; UC: Uncommon; R = Rare. This system is based on the observations made over one year.

Note: Additional information about the organism, wherever exists, is provided in the textual part of the report along with the image code.

3. Disclaimer

This study was initiated under the permission received from the PCCF (Wildlife), Madhya Pradesh, Bhopal, communication code क्रमांक / तकनीकी-I / 386 dated January 20, 2014. As per the permission, no sampling was undertaken inside tiger reserve. Photography was used as a tool to document the insect and spider diversity of KTR.

Two kinds of photographic methods were used; one on the field during transect walk, and second during night at a light source such as tube light and bulbs, hence some images photographed on a white surface appear so since they were photographed on a white curtain near a source of artificial light.

In some cases photography was not possible since the subject was difficult to approach. In such instances images have been sourced from different locality of the exact same or related species.

The identifications in this report are therefore based solely on photographs, and hence some organisms have not been identified up to species-level since, taxonomically speaking, species-level identifications of insects and spiders require handling of the specimen. The morphospecies identifications were undertaken with the help of experts in the field of entomology and arachnology, and by referring to literature (a bibliography of literature referred to is provided in Section V).

There may be instances of erroneous identifications, and the author of this report takes the responsibility of the errors which will be corrected in a corrigendum to the current report.

The views expressed in this report are solely that of the author and do not represent the views of the persons whose names are mentioned in this report.

4. About Kanha Tiger Reserve

Kanha Tiger Reserve (KTR) lies in the Central Indian Highlands, and is one of India's first National Parks to be declared a Tiger Reserve under Project Tiger in the year 1973. The birth of this reserve is in the union of two important valleys in the region – Banjar Valley in the south-west, and Halon Valley to the north-east. Both these rivers take birth in the densely forested hills of Maikal ranges of KTR, and have been quenching the thirst of wildlife and humans alike for centuries as they pass through fertile plains and evergreen valleys to join Narmada River further north.

The conservation history of these two valleys dates back to the 1900s, when they were primarily used as hunting blocks. Tales of hunting of tigers and the many-antelered Hard-ground Barasinghas were once common in the region, until around the 1950s when a huge swathe of the area was declared a sanctuary for the protection of these animals. After over ten decades, the area which was once famous for its *shikar* is now well known and reputed for its conservation measures of India's two most enigmatic species – the tiger and the barasingha, in addition to a number of other species.

Spread over an area of 2051 sq. km, it lies under the political boundary of the state of Madhya Pradesh, in the districts of Mandla and Balaghat, and is managed by the Forest Department of the Government of Madhya Pradesh.

The coordinates of KTR are 22°7' to 22°27'N Longitude; 80°26' to 81°3'E Latitude.

Fig 1. Map of Kanha Tiger Reserve

4.1 Geography

Kanha Tiger Reserve (KTR) lies in the Satpuda-Maikal Range, near the southern edge of the Central Indian Highlands. Biogeographically, it lies on the Deccan Peninsula's central plateau (MoEF and Kalpavriksh 2004), and is characterised by moist and dry deciduous, and moist peninsular Sal forests. It is primarily the soil type that gives KTR its myriad vegetation types. The reserve has characteristic plateaus formed by the Maikal ranges that run along the eastern boundary of the reserve, locally called as "Dadar" (Management Plan for Kanha Tiger Reserve 2001-02 to 2010-11). These plateaus are characterised by laterite rocks with a peculiar red colour. They form excellent grounds for insects and spiders preferring grassland habitats, which are quite distinct from the assemblages found in other types of vegetation in the valleys. The banks of watercourses and valleys consist of sandy alluvium, favoured extensively by Sal trees. Shards of glinting mica are commonly seen in such sandy soils, and these habitats are excellent for insects such as Tiger Beetles.

4.2 Climate

KTR falls under the "tropical wet and dry" climatic zone of India. It experiences three distinct seasons, summer (early March to June-mid), monsoon (June-end to September), and winter (October to late February). Temperatures between 19°C and 46°C have been recorded between March and May during summer, with humidity between 10% and 91.3%. Summer is the season when the second generation of insects is engaged in mating and nesting, as is commonly observed amongst wasps and flies.

As much as 1400mm rainfall is received during monsoon season (Management Plan for Kanha Tiger Reserve 2001-02 to 2010-11), and the increase in density and diversity among insects and spiders corresponds directly to the increase in the plant biomass. This is primarily the season when the young ones of invertebrates mature.

Winter sees a marked drop in temperatures, with as low as -2°C recorded (Management Plan for Kanha Tiger Reserve 2001-02 to 2010-11) during December, to a maximum in the range of 20 to 25°C. The post-monsoon and early-winter days show high insect and spider activity as adults, the first generation that took birth in monsoon, mate and lay eggs before the dry season progresses.

4.3 Vegetation type

KTR lies in the Indo-Malayan ecozone, and the Tropical Deciduous type of India's ecoregion, characterised by moist- and dry-deciduous forests that typically shed leaves at least once in a year – especially during the early summer months. The Management Plan for Kanha Tiger Reserve (2001-02 to 2010-11) identifies the vegetation type of KTR as Moist Peninsular Sal Forests (3C/C2), southern tropical moist mixed (3A/C2a), and dry mixed deciduous forests (5A/C-3). Under this project, the working classification of the vegetation type was broadly classified into Sal forests, mixed deciduous forests, bamboo dominant forests, and grasslands (including meadows and plateaus) depending upon the vegetation type.

4.4 Biodiversity

KTR's biodiversity is characteristic of the ecoregion it belongs to, and can be clearly identified from its flagship fauna, the mammals and birds. Summary of the biodiversity of KTR recorded in literature is given below.

Table 1: Species diversity of KTR recorded in literature

Type	**Species diversity**	**Reference**
Flora		
Pteridophytes	22	Pandey and Namdeo 2009
Gymnosperms	2	Pandey and Namdeo 2009
Angiosperms	829	Pandey and Namdeo 2009
Fauna		
Mammals	59	Harshey and Chandra 2001
Birds	270	D'Cunha, pers. comm.
Snakes	22	Thakur 2011
Invertebrates	250	Chandra *et al* 2012; Chandra *et al* 2007
TOTAL	1454	

The species diversity recorded above only represents studies conducted on specific groups of flora and fauna. These figures do not take into consideration groups of animals such as lizards, amphibians, and several other invertebrates such as bees and wasps. The predicted number of species diversity of KTR could be anywhere between 2000 and 5000, dominated mostly by insects, and closely followed by plants, arachnids, and birds.

5. Methodology

5.1 Field Work

Fieldwork was undertaken during the period of March 2014 to February 2015. Areas of core and buffer zone were studied using various field techniques including transect and quadrat method, random survey, and light trap. These methods were utilized for different groups of insects and spiders. Transect method and random survey focused more on flying insects such as butterflies and dragonflies, quadrat method focused more on density studies of ground dwelling insects such as crickets, cockroaches, ants, and others, and light trap focused on crepuscular and nocturnal species. Line transect and quadrat methods were extensively used during summer season in Mukki, Samnapur, Khapa, and Khatia ranges of KTR to study the density and diversity of these organisms during summer months. Photography was used as a key tool in identification of the subjects.

5.1.1 Line transect method

This method is commonly used to study the diversity of plants and animals of a certain area. Line transect method was undertaken on established transects used for monitoring mammal density of KTR. Lines of 1 km each were surveyed for direct sightings of insects and spiders on and around transects within a distance of 5m on each side. A total of 36 transects were surveyed divided equally for four types of vegetations, viz. Sal dominant forests, mixed deciduous forests, bamboo dominant forests, and grasslands. This method was specifically used to document diversity of butterflies, dragonflies and damselflies, and large spiders in the four vegetation types of KTR.

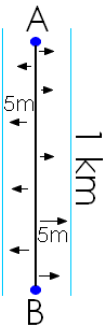


Fig 2. Line transect

5.1.2 Quadrat method for insects and spiders

This method is commonly used to study the density and diversity of plants and animals as an estimate of the actual abundance of the species in an ecosystem. It also helps understand population assemblages of animals in an ecosystem, and help deduce information on the reasons of such assemblages. In this study, a total of 180 quadrats of 2x2m area were laid across the length of 1 km transects at intervals of 250m. A total of 5 quadrats were laid on each transect. The area for quadrats was randomly assessed by throwing a bamboo stick away from the

transect. GPS coordinates were recorded using Garmin etrex 20, and temperature and humidity recorded using Mextech TM-1 digital thermometer for each quadrat. A time period of 10 minutes was dedicated to one quadrat, where one person was engaged in counting insects and spiders in the quadrat area, and one wrote down the sightings. Counting was undertaken in anti-clockwise direction and ended in the middle of the quadrat. Area under and above the leaf litter, and area to the height of the person counting was considered as the quadrat area (Refer to *Fig 3. Quadrat method*).

5.1.3 Random survey

Random survey focused on documenting the diversity of insects and spiders as and when they were observed. This was particularly helpful since most were not seen during line transect and quadrat methods. Random survey was undertaken throughout the year, and was especially crucial in observing behaviour such as hunting and courtship which could not be documented during time-bound surveys.

5.1.4 Light trap

Light trap method is commonly used by taxonomists for sampling of invertebrates for species determination. For this project, it was modified solely for the purpose of photographing crepuscular and nocturnal species of insects and spiders. It is estimated that over 60% of invertebrate diversity is nocturnal in nature, making the use of this method important in biodiversity documentation studies. Insects such as moths and beetles are especially easily documented using this method. A white curtain was displayed near an artificial source of light such as a CFL bulb or a tube light under a tree in an open area, and insects visiting the light were documented.

5.2 Vegetation type

Quadrat method was used to estimate the vegetation type of a given area. A quadrat of 25x25m was laid out around the 2x2m quadrat (see *5.1.2 Quadrat method for insects and spiders*). This was undertaken to estimate the tree cover and the habitat type of the area that surrounded the micro-habitat utilized by insects and spiders. Trees were measured for their tree

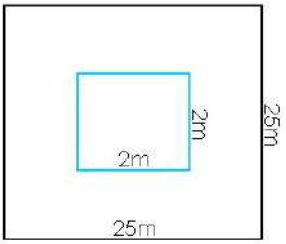


Fig 3. 25x25m quadrat method for vegetation, and 2x2m for insect and spider density analysis

circumference at breast height (CBH) using a measuring tape; trees with ≥30cm CBH were considered as mature trees. The quadrats also considered bamboo islands as an individual unit, and were counted to understand the species composition in the quadrat.

Tree species identification was done on the field using field guides and the knowledge of the forest guards. A total of 35 species of trees were identified in the quadrat.

Based on the tree composition, four vegetation types were identified; viz. Sal dominant forests (SD), mixed deciduous forests (MD), bamboo dominant forests (BD), and grasslands which lacked any tree growth. The composition of tree species for three vegetation types is given below.

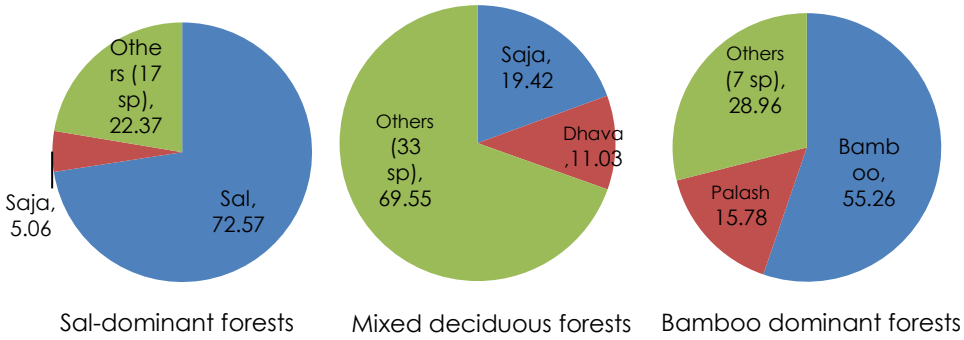


Fig 4. Percent tree composition for three vegetation types

5.3 Temperature and Humidity

Temperature (T°C) and humidity (%H) was recorded between March and May 2014 to assess the impact such abiotic factors have on the assemblages of these invertebrates during summer. T and H readings were taken using Mextech TM-1 digital thermometer. Three readings were noted for all quadrats by placing the thermometer in three different locations within the quadrat, and the average was calculated to study variation in T and H in the four vegetation types discussed above.

This was undertaken to test the hypothesis that T and H impact the density and diversity of invertebrates, thereby giving us a hint at their preferred vegetation types that offered optimum T and H. Although no significant differences in T and H were observed amongst the vegetation types in the three month period (see

Fig 5. T°C and %H observed in four vegetation types of KTR), it was inferred that, irrespective of T and H of the habitat, factors such as availability of ground cover, shade, and presence of food plays a significant role than temperature and humidity (*more details in Section I, Ch. 14 and Section II, Ch. 4*).

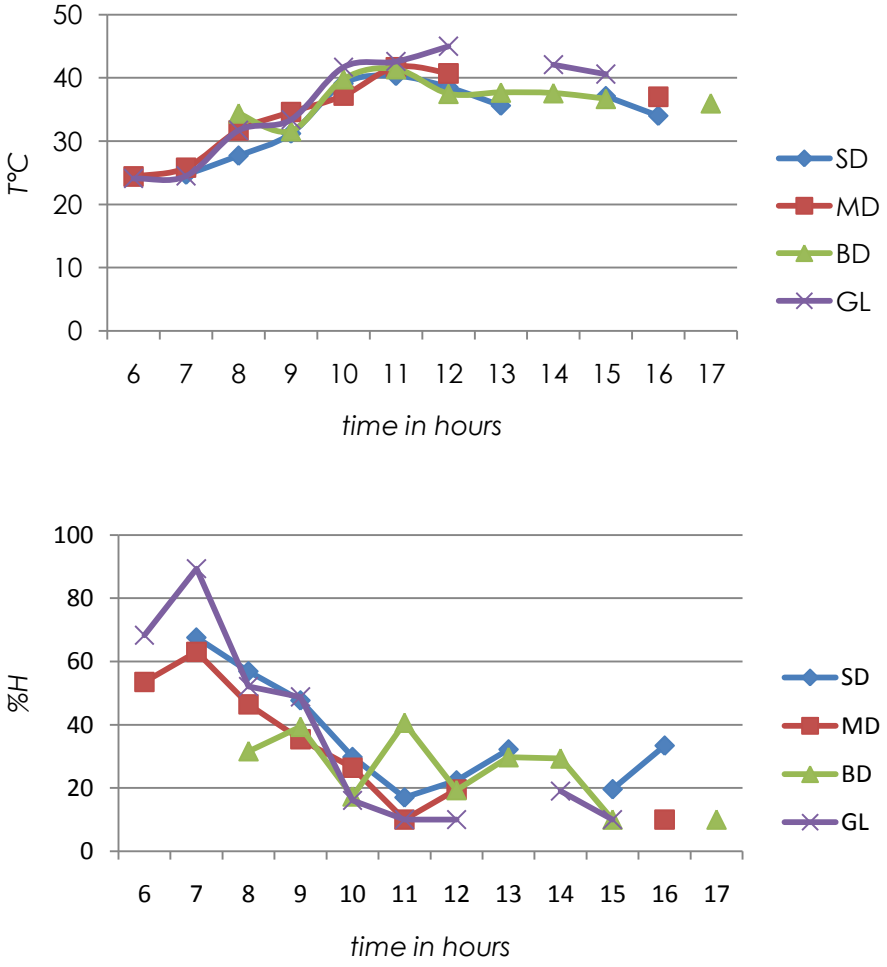


Fig 5. T°C (top) and %H (above) observed in four vegetation types of KTR for March to May
Sal Dominant = SD; Mixed Deciduous = MD; Bamboo Dominant = BD; Grassland = GL

Further studies encompassing all the seasons and focusing on the role T and H play in species diversity and density could throw more light into how invertebrate assemblages are affected by these abiotic factors.

5.4 Identifications and data analysis

Insects and spiders were documented through photography using field techniques mentioned above. A hand lens, and a DSLR camera, Canon 60D, with 18-55mm and 55-250mm lenses along with macro filters, were used to photograph these organisms for identification purposes. Due to constraints in observation and documentation of some organisms measuring less than 5mm, only those which could be identified from photographs are considered here.

The general classification system followed under this project is as follows:

Order → Family → Genus → Species

5.4.1 Identification of insects

On-field photographs were obtained which aided in identifications. Additional information, such as the ecology and behaviour were also noted. Identifications focused on external morphology of the organisms, and were made based on identification keys and photographs provided in literature. Insects were first identified in the Order they belonged to. Identification keys further helped for identification up to Family, Subfamily, Genus, and Species level. Advice was sought from entomologists for assistance in identifications wherever possible.

5.4.2 Identification of spiders

A system similar to the one used for identification of insects was applied while studying spiders. Spiders fall in a single Order Araneae, and are differentiated into various Families based on their eye-patterns and behaviour. Spiders were photographed on the field and literature consulted for their identification based on external morphology and eye pattern.

5.4.3 Data analysis

For density studies, only Orders and Families we considered since subfamily and genus/species-level identifications were not possible on field. Given that Orders and Families largely reflect the habitat preferences of animals (which are in turn based on their physiological, morphological, and feeding habits, amongst

others), the density analysis reflected two key factors: (a) their preferred sites in terms of prey density, and (b) their preferred sites in terms of availability of optimum conditions.

Density studies were undertaken only during March to May 2014. Individual insects and spiders were counted during quadrat and transect surveys (see *5.1 Fieldwork*), and classified according to their Orders. Family-level density studies were only undertaken for Hymenoptera, Diptera, Orthoptera, and Blattodea.

Percent Relative Abundance was calculated for the density of all the Orders and Families in each of the four vegetation types, viz. Sal Dominant (SD), Mixed Deciduous (MD), Bamboo Dominant (BD), and Grasslands (G), to understand their composition and deduce reasons for this distribution. Analysis of density studies is given in Section I, Ch. 14 and Section II, Ch. 4.

Section I

INSECTS

1. Introduction

Insects are the most diverse animals on Earth, outnumbering all the others in terms of species diversity and population. They belong to Phylum Arthropoda (*arthro* = joint; *poda* = foot), and are classified in their own Class Insecta based on some typical characters. Insects have a hard exoskeleton made up of chitin. Their body is divided into three parts – head, thorax, and abdomen, and contains a pair of antennae, three pairs of legs, and two pairs of wings. They breathe through little holes on their abdomen called spiracles.

Class Insecta is further divided into 32 orders (Wheeler *et al* 2001), the majority of them represented by Coleoptera, Lepidoptera, Diptera, and Hymenoptera. They occupy virtually every terrestrial and freshwater niche that exists, and play a significant role in the complex food-web of an ecosystem. They are an indicator of ecosystem equilibrium – in other words, an imbalance in their populations can affect an ecosystem positively or negatively. For example, a small population of grasshoppers does no harm to plant growth, and serves as a food-source to many insectivorous animals, however a significant rise in their population can prove devastating to an ecosystem, which is observed when locusts swarm and damage crops. Studying this group of animals is therefore crucial to understand ecological functioning of a certain landscape.

Insects play a significant role in various basic functions of an ecosystem, such as pollination, degradation and decomposition, biological control, and serve as a rich source of food for other organisms. Their secondary, human-related importance is in forensic science (a field called forensic entomology), food preparations (as food additives), as well as in direct consumption by many communities across the globe. Perhaps their well known secondary importance comes in the form of aesthetics, as butterflies, moths, and beetles are commonly reared or welcomed into the gardens to add a movement of flutter and a flash of colour to a manicured landscape.

Insects face threats similar to the vertebrates. Degradation of ecosystems significantly affects insect diversity and community assemblages, and they are probably the first representatives of showing minute changes in an ecosystem. Habitat destruction and fragmentation threaten insects in ways similar to large vertebrates. The United Nations World Commission on Environment and Development report *Our Common Future* (1987) states, "We have no accurate figures on the current rates of extinctions, as most of the species vanishing are those least documented, such as insects in tropical forests". Similar to the

charismatic species such as the tiger, insects are poached for their vivid colours. Species of butterflies, beetles, and other "appealing" ones are killed and sold illegally as collection items.

About 499 species of insects are protected under the Wildlife Protection Act 1972. 127 species of insects (mostly butterflies) in India are protected under Schedule I, receiving the highest conservation priority as the tiger. 354 species of insects (mostly beetles, butterflies and moths) are protected under Schedule II, and 18 species under Schedule IV. Awarding protection status to these species is a priority to the conservation of biodiversity of India, since they also require undisturbed habitats and areas for dispersal (especially for migratory insects) as their vertebrate counterparts.

Traditionally, insects are used for a number of purposes, and most of these uses are being followed for many centuries, making them not only a viable venture for forest-dependent communities, but also an ecologically sustainable one. Insects such as honeybees are cultured for their honey by a well established technique called apiculture. Honey obtained from Indian Honeybee (*Apis dorsata*) in Kanha sells for as much as Rs. 150 a litre, and that from the stingless bee (*Lisotrigona* sp.) for as much as Rs. 200 a litre. Lac, which is produced from an insect called Lac insect (*Kerria lacca*), is also undertaken as a venture in the area, and yields as much as Rs. 100 per kilogram. In other parts of the country, Weaver Ants (*Oecophylla smargdina*) are used for consumption, as are several species of beetle grubs and Hemipteran bugs. Oudhia (2005) reported uses of as many as 500 species of insects and mites in traditional medicine in Chhattisgarh.

Indirect values of insects are more than their direct uses. In Kanha, Indian Honeybee (*Apis dorsata*) has been observed feeding on nectar and collecting pollen exclusively on Mahua (*Madhuca indica*) flowers during summer. I speculate that they play a key role in pollination of Mahua trees, and provide a valuable ecosystem service to humans (wet Mahua flowers sell for around Rs. 9 per kg, dried for around Rs. 25, and the seed for Rs. 22 per kg). Flies such as *Lathyrophthalmus* sp. have been observed feeding on Jamun (*Syzygium cumini*) flowers, and possibly enable pollination of this tree (Jamun fruits sell for around Rs. 10 per kg). Fig wasps are also abundantly found in Kanha, and are the sole pollinators of a number of Fig species which form a major diet of several birds and mammals, as well as human beings.

Insects, in their small lifespan, provide us with a multitude of selfless ecological services. This section intends to record their lives in Kanha Tiger Reserve and their potential impacts on the ecosystem.

2. Observations

Considering the sheer number of diversity of insects in India's subtropical forests, a generous effort has been made to document the most common, and some rather uncommon or rare, species of insects occurring in KTR.

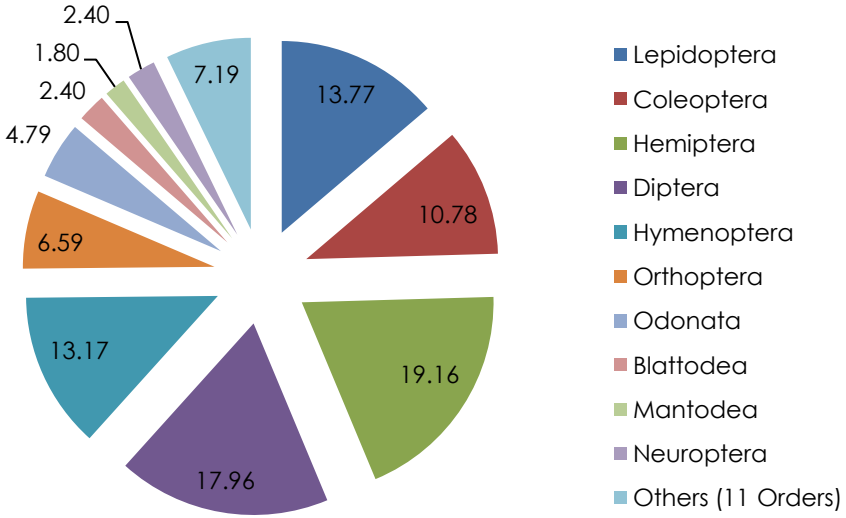
A total of 436 individual specimens were recorded during the present study belonging to 21 orders. Most of the specimens were identified upto genus or species-level, except for 74 specimens which were only identified upto family-level. Nine non-insect orders were also recorded, represented by at least 9 specimens. With respect to the present study, Lepidoptera is represented by the largest number of species, followed by Hymenoptera, Coleoptera, Hemiptera, Diptera, and Odonata. In terms of Family-level diversity, Hemiptera shows the highest diversity, followed by Diptera, Lepidoptera, Hymenoptera, and Orthoptera.

Density-wise, the most common social insect is ants, followed by termites, and Indian honeybee. In terms of solitary insects, the most common is crickets (Orthoptera), followed by moths and butterflies (Lepidoptera), true bugs (Hemiptera), bees and wasps (Hymenoptera), cockroaches (Blattodea), true flues (Diptera), dragonflies and damselflies (Odonata), with other miscellaneous orders making up a rather small percent of total density.

Sal dominant forests contain the highest density and diversity of insects, followed by mixed deciduous forests, bamboo dominant forests and grasslands. This trend was observed during summer months, and is mainly attributed to the biotic and abiotic factors which largely govern insect assemblages during harsh seasons and low availability of food sources, such as daily temperature fluctuation, dense leaf litter creating favourable microhabitats, and availability of shade. Temperature and humidity seemed to be a limiting factor only in open habitats with no canopy, such as grasslands.

This section discusses the 21 insect orders in detail, along with 9 non-insect orders sharing the same habit and habitat with insects. Emphasis has been made on making photographs available for on-field identification purposes, along with short information on the insect's basic ecology and behaviour as was observed during the study.

References for identification keys, host plants and lifecycle, and general behaviour can be referred from the Bibliography in Section V.



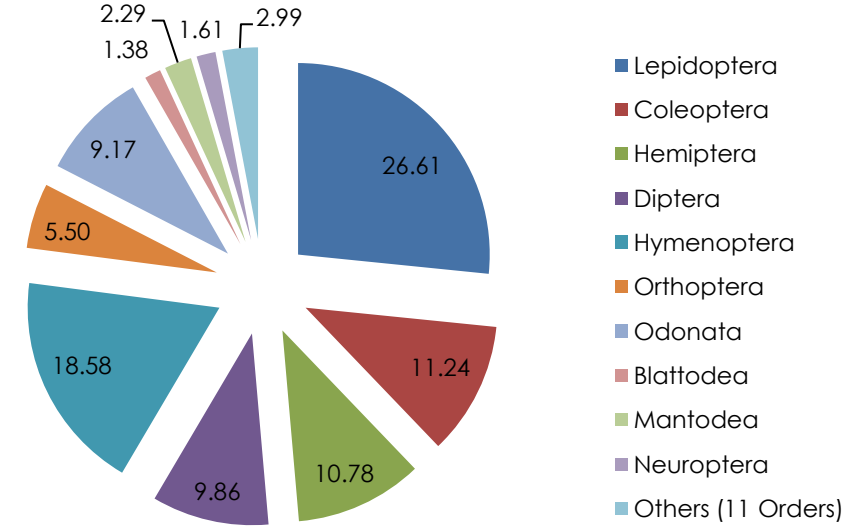


Fig 6. Family-wise %composition of insect orders (top); Specimen-wise %composition of insect orders of KTR (above) of KTR.

3. Lepidoptera

Lepido = scaly; *ptera* = wings

Lepidoptera encompasses a group of insects commonly called butterflies and moths. They are distinctly identifiable from their large, scaly wings, elongated soft bodies, and two long antennae. Quite often their wings are vividly coloured, while some have evolved to match the shape and colour of leaves. Their lifecycle is divided into two parts, showing complete metamorphosis. Once the female lays an egg on a plant (called host plant), a caterpillar emerges and feeds voraciously on the leaves. The caterpillar is a soft bodied larval stage in Lepidoptera, and continues to moult as it grows in size. Once fully grown, the caterpillar pupates, transforming from an active larva to a stationary stage where its internal biochemistry helps it transform. Butterflies commonly form pupas with only a thin layer of protective membrane around them, whereas some moths spin cocoons around them using a silky secretion, the best example of which is the Silkworm, the larva of the Tassar silk moth (*Antheraea mylitta*). An adult with small, wrinkled wings emerges from the pupa once the transformation is complete, and stays still as hemolymph is pumped into the veins of the wings which enables them to fly. Adults when fully mature feed on a variety of sources, such as nectar from flowers, tree sap, salts and minerals from moist areas, as well as nutrients from scat and carrion. Most common food associated with this group of insects is nectar, which also makes them pollinators of a number of plants. They use their specialized mouthpart called proboscis as a straw to suck the liquid contents.

Lepidoptera is a large order encompassing nearly 180000 species in 126 families. About 1800 species of butterflies have been recorded and more than 12000 species of moths are estimated to be present in India. Studies on butterflies in central India were conducted by Chandra et al (2007), where the authors published a checklist of butterflies of Madhya Pradesh (MP) and Chhattisgarh (CG) based on first-hand records and literature. Over 174 species were recorded in the two states by the authors, of which 63 were recorded in Balaghat and 65 in Mandla districts of MP. Since KTR falls within the boundary of these two districts, it is assumed to have the diversity represented in the two districts by the authors.

In the current study, 79 species of butterflies were observed, of which 20 are new records for the two districts recorded by Chandra et al (2007), taking the total

number of species of butterflies observed in KTR and as per literature to 87. A checklist of butterflies of KTR is provided in Section IV Annexures.

Studies pertaining to moths in the region were undertaken by Chandra et al (2007b) who recorded 313 species from MP and CG. The authors also acknowledged the fact that most studies pertaining to moths focus solely on the pestiferous groups, which is one of the main reasons why so little is known about the diversity of moths in the central Indian region. The authors identified 57 species belonging to 9 families from KTR.

In this study, 36 species of moths were identified belonging to 15 families. Although this is just a representational fraction of the moth diversity of KTR, I guesstimate the total number to be anywhere above 200 species. The combined number of species of moths recorded in KTR under the current study and in literature is 92 under 18 families.

Overall, 178 species belonging to 23 families has been identified under Order Lepidoptera in KTR.

This chapter provides photographs of 79 species of butterflies and 36 species of moths identified in the current study, along with observations and notes on their behaviour.

Plate 1

1.a. Blue Mormon; *Papilio polymnestor;* Papilionidae: R
Seen flying in Sal and Mixed Deciduous forests.

1.b. Common Mormon; *Papilio polytes*; Papilionidae: C
Often seen visiting garden flowers.

1.c. Common Rose; *Papilio aristolochiae*; Papilionidae: C
Often seen during mud-puddling.

1.d. Crimson Rose; *Papilio hector*; Papilionidae: C
Often seen during mud-puddling.

1.e. Lime Butterfly; *Papilio demoleus demoleus*; Papilionidae: C
Often seen visiting garden flowers; Caterpillars considered pest on some commercial *Citrus* sp.

1.f. Spot Swordtail; *Graphium nomius nomnius*; Papilionidae: C
Seen flittering in all vegetation types; seen mud-puddling near moist ground.

1.g. Tailed Jay; *Graphium agammenon*; Papilionidae: UC
Seen flittering near Lantana thickets.

1.h. Common Jezebel; *Delias eucharis*; Pieridae: C
Seen in all vegetation types, mostly in gardens and fields of Radish and Carrots.

1.i. Common Grass Yellow; *Terias hecabe simulata*; Pieridae: C
Seen flittering close to ground in all vegetation types; seen mud-puddling near moist ground.

1.j. Common Emigrant; *Catopsilia ponona*, Pieridae: C
Seen flittering in all vegetation types; seen mud-puddling near moist ground.

1.k. Common Emigrant; *C. ponona* form *catilla*; Pieridae: UC
A morph of female Common Emigrant

1.l. Mottled Emigrant; *Catopsilia pyranthe pyranthe*; Pieridae: C
Seen flittering in all vegetation types; seen mud-puddling near moist ground.

1.m. Striped Tiger; *Danaus genutia*; Nymphalidae: C
Seen in all vegetation types.

1.n. Plain Tiger; *Danaus chrisippus*; Nymphalidae: C
Seen in all vegetation types, especially near *Calotropis gigantea*, *Heliotropium strigosum*, and *Crotalaria* sp.

1.o. Spotless Grass Yellow; *Eurema laeta*; Pieridae: UC
Seen flying close to ground.

Plate 1

Plate 2

2.a. Common Wanderer; *Pareronia valeria hippie*; Pieridae: UC
Occasionally seen flying in Mixed Deciduous forests.

2.b. Pioneer; *Belonois aurota aurota*; Pieridae: C
Seen roosting in evening in Bamboo groves and edge of grasslands.

2.c. Psyche; *Leptosia nina nina*; Peridae: C
Seen flying close to the ground in forested areas.

2.d. Blue Tiger; *Trimula limniace leopardus*; Nymphalidae: C
Seen fluttering close to flowering plants.

2.e. Common Leopard; *Phalanta phalanta*; Nymphalidae: C
Seen feeding on flowering trees such as Jamun, and basking on herbs.

2.f. Painted Lady; *Cynthia cardui*; Nymphalidae: UC
Seen basking on herbs close to ground.

2.g. Common Indian Crow; *Euploea core core*; Nymphalidae: C
Seen in all vegetation types, especially near *Heliotropium strigosum*, and *Crotalaria* sp.

2.h. Great Eggfly; *Hypolimnas bolina*; Nymphalidae: C
Seen basking on herbs; males are territorial. Females mimic Common Indian Crow.

2.i. Danaid Eggfly; *Hypolimnas misippus*; Nymphalidae
Seen basking on herbs; males are territorial. Females mimic Striped Tiger.

2.j. Common Evening Brown; *Melanitis leda ismene*, Nymphalidae: C
Crepuscular; commonly seen at lights during evening and night hours.

2.k. Long-brand Bushbrown; *Mycalesis visala visala*; Nymphalidae: C
Seen flying close to ground in dense undergrowths; most common in Monsoon.

2.l. Long-brand Bushbrown; *M. visala visala* Dry Season Form; Nymphalidae: C
A dry season morph; this morph is most common during dry seasons.

2.m. Common Fourring; *Ypthima huebneri*; Nymphalidae: C
Seen flying close to ground in forest undergrowth and grasslands.

2.n. Common Tree Brown; *Lethe rohira*; Nymphalidae: UC
Seen flying close to ground in bamboo groves.

2.o. Bamboo Tree Brown; *Lethe europa europa*; Nymphalidae: C
Seen flying close to ground in bamboo groves.

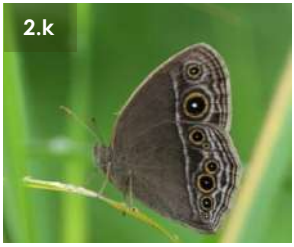


Plate 2

Plate 3

3.a. Chocolate Pansy; *Precis iphita pluviatilis*; Nymphalidae: UC
Seen gliding in Mix Deciduous forests or feeding on flowers of *Lantana*.

3.b. Grey Pansy; *Junonia atlites*; Nymphalidae: C
Seen basking or flying near shrubs; common near forest edges.

3.c. Peacock Pansy; *Junonia almana almana*; Nymphalidae: C
Seen basking or flying near shrubs; common near forest edges.

3.d. Yellow Pansy; *Junonia hierta hierta*; Nymphalidae: C
Especially common during summer-end; prefers clearings such as forest paths to perch on.

3.e. Blue Pansy; *Junonia orithya swinhoei*; Nymphalidae: C
Especially common during summer-end; prefers clearings such as forest paths to perch on.

3.f. Lemon Pansy; *Junonia lemonais vaisya*; Nymphalidae: C
Seen basking or flying near shrubs; common in all vegetation types.

3.g. Common Sailer; *Neptis hylas astola*; Nymphalidae: C
Seen basking or flying near shrubs; common in all vegetation types.

3.h. Short Banded Sailer; *Phaedyma collemella*; Nymphalidae: C
Seen basking or flying near shrubs; common in all vegetation types.

3.i. Staff Seargent; *Athyma selenophora*; Nymphalidae: UC
Seen basking or flying in forest clearings.

3.j. Commander; *Moduza procris procris*; Nymphalidae: C
Seen basking or flying near shrubs; often mud-puddles and seen in gardens.

3.k. Baronet; *Symphaedra nias*; Nymphalidae: C
Seen basking or flying in forest floor; common in all vegetation types. Larval host plant is Tendu (*Diospyros melanoxylon*) in post-monsoon months.

3.l. Common Baron; *Euthalia aconthea garuda*; Nymphalidae: C
Seen basking or flying near shrubs; often mud-puddles and seen in gardens.

3.m. Gaudy Baron; *Euthalia lubentia*; Nymphalidae: UC
Seen mud-puddling on moist banks of ponds and rivers.

3.n. Tawny Rajah; *Charaxes bernardus*; Nymphalidae
Seen mud-puddling on wet banks of pinds and rivers.

3.o. Black Rajah; *Charaxes solon*; Nymphalidae
Seen mud-puddling on moist banks of ponds and rivers.

Plate 3

Plate 4

4.a. Common Palmfly; *Elymnias hypermnestra*; Nymphalidae: UC
Often seen in Bamboo plantations with moist soil.

4.b. Orange Oakleaf; *Kallima inachus heugeli*; Nymphalidae: UC
Seen mud-puddling on moist banks of streams, easy to identify while flying.

4.c. Tawny Coster; *Acraea trepiscore*; Nymphalidae: C
A slow-flight butterfly; commonly seen flying near thickets in Mixed Deciduous forests. Often found near its larval food plant *Ichnocarpus fructescens*.

4.d. Suffused Double Banded Judy; *Abisara bifasciata*; Riodininae; Lycaenidae: C
Found in forest understory perched on leaves. Typically moves around in a circle when perched.

4.e. Angled Sunbeam; *Curetis acuta*; Lycaenidae: UC
Seen mud-puddling on wet banks of ponds.

4.f. Angled Pierrot; *Caleta decidia*; Lycaenidae: C
Common in all vegetation types, mostly seen mud-puddling in dense forests.

4.g. Common Pierrot; *Castalius rosimon rosimon*; Lycaenidae: C
Common in all vegetation types, including degraded forests.

4.h. Red Pierrot; *Talicada nyseus*; Lycaenidae: C
More common in gardens rather than forests due to presence of larval host plant *Kalanchoe lanceolata*.

4.i. Zebra Blue; *Leptotes plinius*; Lycaenidae
Flies close to ground, more common in gardens than forests.

4.j. Dark Cerulean; *Jamides bochus bochus*; Lycaenidae
Common in all vegetation types, often visits garden flowers.

4.k. Common Cerulean; *Jamides celeno aelianus*; Lycaenidae
Common in all vegetation types, including degraded forests.

4.l. Forget-me-not; *Catochrysops strabo strabo*; Lycaenidae: UC
Often seen in forest clearings where they prefer to bask; rapid erratic flight.

4.m. Gram Blue; *Euchrysops cnejus*; Lycaenidae: C
Common in Mixed Deciduous Forests, including degraded forests.

4.n. Plains Cupid; *Chilades pandava*; Lycaenidae: C
Common in all vegetation types and gardens.

4.o. Indian Cupid; *Everes lacturnus*; Lycaenidae : UC
Seen feeding on small herbs and basking close to ground along forest edges.

Plate 4

Plate 5

5.a. Lesser Grass Blue; *Zizina otis sangra*; Lycaenidae: C
Commonly seen resting on the ground waving their wings.

5.b. Tiny Grass Blue; *Zizula hylax*; Lycaenidae: C
Commonly seen resting on the ground waving their wings.

5.c. Plain Hedge Blue; *Celastrina lavendularis puspa*; Lycaenidae: UC
Often seen basking near a waterbody, or puddling on the moist ground.

5.d. Common Silverline; *Spindasis vulcanus vulcanus*; Lycaenidae: UC
Often seen basking on shrubs.

5.e. Large Oakblue; *Arhopala amantes*; Lycaenidae: C
Locally common wherever larval host plant Saja (*Terminalia tomentosa*) is present. More commonly encountered in summer than any other season.

5.f. Leaf Blue; *Amblypodia anita*; Lycaenidae: UC
Often seen puddling on the moist ground.

5.g. Common Guava Blue; *Virachola Isocrates*; Lycaenidae: R
Seen basking on trees; often near Guava trees.

5.h. Indian Red Flash; *Rapala iarbus*; Lycaenidae: R
Seen basking on herbs or mud-puddling near moist banks of ponds and rivers.

5.i. Apefly (unconfirmed record); *Spalgis epius* Pupa; Lycaenidae: R
Only pupa has been recorded on a dried Sal leaf. Record is still uncertain.

5.j. Pea Blue; *Lampides boeticus*; Lycaenidae: C
Often observed in open forest meadows, common during monsoon near *Pea* sp.

5.k. Brown Awl; *Badamia exclamationis*; Hesperiidae: R
Seen feeding on shrubs like Lantana; often visit human habitations for shade.

5.l. Malabar Flat; *Celaenorrhinus ambareesa*; Hesperiidae: UC
Seen during monsoon feeding on ephemeral flowers such as *Impatiens balsamina*.

5.m. Tricolour Pied Flat; *Coladenia indrani*; Hesperiidae: UC
Seen feeding on flowers including Lantana; common during monsoon but also seen during summer.

5.n. Common Small Flat; *Sarangesa dasahara*; Hesperiidae: C
Often seen basking on the ground.

5.o. Dark Palm Dart; *Telicota ancilla bambusae*; Hesperiidae: C
Often seen basking on tall shrubs; feeds on flowers of herbs and shrubs.

Plate 5

Plate 6

6.a. Straight Swift; *Paranara naso bada*; Hesperiidae: C
Common in degraded forests and agricultural fields.

6.b. Rice Swift; *Borbo cinnara*; Hesperiidae: C
Common in degraded forests and agricultural fields, especially rice fields.

6.c. Common Grass Dart; *Taractrocera maevius*; Hesperiidae: UC
Occasionally seen basking on low herbs.

6.d. Indian Skipper; *Spialia galba*; Hesperiidae: UC
Occasionally seen basking on low herbs.

6.e. Indian Palm Bob; *Suastus gremius*; Hesperiidae: UC
Occasionally seen basking on tall shrubs or feeding on *Lantana camara* flowers.

6.f. Common Banded Awl; *Hasora chromus*; Hesperiidae: C
Often observed visiting shaded places, including human-made constructions.

Plate 6

Plate 7

7.a. Lesser Death's Head Hawkmoth; *Acherontia styx*; Sphingidae: C
Commonly seen near lights.

7.b.Common Velvet Hawkmoth; *Clanis phalaris*; Sphingidae: C
Occasionally seen near lights.

7.c. Levant Hunter Hawkmoth; *Theretra alecto*; Sphingidae: C
Occasionally seen near lights.

7.d. Oleander Hawkmoth; *Daphnis nerii*; Sphingidae: C
Commonly seen near lights.

7.e. *Daphnis nerii* Caterpillar; Sphingidae: C
Caterpillar of *D. nerii*. Larval host plant includes *Nerium indicum* and *Tabernaemontana* sp. variety.

7.f. Convolvulus Hawkmoth; *Agrius convolvuli*; Sphingidae
Occasionally seen near lights.

7.g. Gliding Hawkmothl; *Ambulyx* sp.; Sphingidae: UC
Occasionally seen near lights.

7.h. Lesser Agnosia; *Agnosia microta*; Sphingidae: C
Occasionally seen near lights especially during monsoon.

7.i. Common Bumble-bee Hawkmoth; *Cephonodes hylas*; Sphingidae: C
Occasionally seen near lights especially during summer and monsoon.

7.j. *Ascotis imparata*; Geometridae: C
Commonly seen near lights especially during monsoon.

7.k. Day-flying Blue Tiger Moth; *Dysphania* sp.; Geometridae: C
Commonly seen flying during day and mud-puddling on moist ground.

7.l. *Synchlora* sp.; Geometridae: C
Occasionally seen near lights especially during monsoon.

7.m. Beetroot Webworm Moth; *Spoladea recurvalis*; Crambidae: C
Commonly seen near lights especially during monsoon. Most common in kitchen gardens. Considered as a pest on Beetroot, Spinach, Groundnut, Carrot, Cucurbits, and Beans.

7.n. Sesame Leaf Roller Moth; *Antigastra catalaunalis*; Crambidae: C
Occasionally seen near lights. Abundant during monsoon.

7.o. *Nymphicula blandialis*; Crambidae: C
Occasionally seen near lights, common in grasses during monsoon.

Plate 7

Plate 8

8.a. *Uthethesia pulchella*; Erebidae: C

Abundant during monsoon, common in open areas with scant undergrowth.

8.b. Owlet Moth; *Spirama retorta*; Erebidae: C

Occasionally seen near lights especially during monsoon. Prefer dense undergrowth areas.

8.c. Owlet Moth; *Spirama retorta* Dark Morph; Eresidae: UC

A less common morph of *S. retorta*. Prefer dense undergrowth areas. Less frequent on lights at night than the common morph.

8.d. *Lymantria* sp.; Lymantriinae, Erebidae: C

Commonly seen in Sal forests than others; less frequent at lights.

8.e. *Lymantria mathura*; Lymantriinae; Erebidae: C

Commonly seen in Mixed Deciduous forests; commonly seen at lights.

8.f. *Lymantria mathura* Caterpillar; Lymantriinae; Erebidae: C

Caterpillar of *L. mathura* feeds on a number of plant species, most commonly recorded in KTR is Saja (*Terminalia tomentosa*).

8.g. *Perina nuda*; Lymantriinae; Erebidae: C

Commonly seen near lights especially during monsoon and winter.

8.h. Hamdmaiden Moth; *Amata* sp.; Arctiinae; Erebidae: C

Commonly seen during the day, especially during monsoon.

8.i. *Rajendra vittata*; Arctiinae; Erebidae: C

Commonly seen near lights especially during monsoon.

8.j. *Paracerura priapus*; Notodontidae: C

Commonly seen near lights especially during monsoon.

8.k. *Trypanophora* sp.; Zygaenidae: C

Commonly seen during the day through all vegetation types in all seasons, most common at the end of monsoon and in winter.

8.l. *Trypanophora* sp. Caterpillar; Zygaenidae: C

Feeds on a number of plants. In KTR, it has been observed on Tendu (*Diospyros melanoxylon*), Rose (*Rosa* sp.), and Lendia (*Laegerstromia* sp.).

8.m. *Belippa* sp. Caterpillar; Limacodidae: C

Seen feeding on Tendu (*D. melanoxylon*). Adult form unknown.

8.n. *Parasa* sp.; Limacodidae: C

Commonly seen near lights especially during monsoon.

8.o. Plume Moth; Pterophoridae: C

Commonly seen near lights at night. Prefers dense undergrowth.

Plate 8

Plate 9

9.a. *Endotricha* sp.?; Pyralidae: C

Commonly seen near lights.

9.b. *Polytela gloriosae*; Noctuidae: C

Commonly seen in gardens or areas with Lily plants (*Crinum* sp.), especially when it is flowering and sprouting new leaves in monsoon.

9.c. Agaristinae; Noctuidae: C

Commonly seen near lights during monsoon. Prefer forested areas with scant undergrowth.

9.d. *Chalciope mygdon*; Noctuidae: C

Commonly seen near lights.

9.e. *Micronia aculeata*; Uraniidae: C

Commonly seen near lights. Perch on short herbs and shrubs during day.

9.f. *Xyleutes persona*; Cossidae: R

Slow in movement; occasionally seen near lights. Larva bore in Casuarina trees.

9.g. Wooly Bear Caterpillar; Eupterotidae: C

Adult form in 9.h. Commonly seen on tree trunks during monsoon. Probably feed on lichen and moss that grows on tree barks.

9.h. *Eupterote undata*; Eupterotidae: C

A large moth. Occasionally seen near lights during pre-monsoon showers

9.i. Indian Luna Moth; *Attacus selene*; Saturniidae: R

A large moth. Occasionally seen near lights during monsoon.

9.j. Bag Worm Moth; Psychidae: C

Adult form unknown. Most abundant of all moths. Feeds on the upper layer of leaves of Sal (*Shorea robusta*). Often seen in their hundreds on a tree. Seem to do little to no damage to Sal trees, however further studies on their lifecycle and impact on Sal trees is required. Adult typically builds a protective cover.

9.k. Bag Worm Moth Cocoon; Psychidae: C

Typically forms a cocoon at the end of a silken stalk.

9.l. Bag Worm Moth Pupa; Psychidae: C

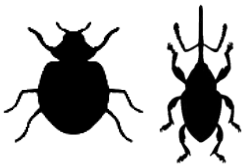
Shape of pupa suggests that it belongs to Lepidoptera. Feeding and protective behaviour indicates that it belongs to Family Psychidae.

9.m. *Maruca vitrata*; Crambidae: C

Commonly seen near lights.

Plate 9

4. Coleoptera



Koleos = sheath; *ptera* = wings

Coleoptera is the largest order of any animal, encompassing an estimated 350000 to 400000 species, making up to 30% of all animals on Earth. Two morphologically distinct groups, the beetles and the weevils, make up this order. Their sheer diversity is reflected in their myriad shapes (from 1mm to 17cm), sizes (up to 17g), colours (from camouflaging browns to vivid shades of red, blue, and green), and feeding habits (detritivores to predators), habitat preferences (deserts to rainforests), and other ecological roles.

Typically, a beetle has a hard exoskeleton, and is distinctly divided into three body parts; head, thorax, and abdomen. The abdomen is covered under two pairs of wings. The first pair is hardened and covers the entire or a part of the abdomen, and is called elytra. The second pair of wings is membranous and generally long, and is used in flight. It is kept folded underneath the elytra when at rest. Beetles, like butterflies, undergo complete metamorphosis. Eggs are generally laid near the preferred larval food, which could either be roots of a tree, leaves, underneath barks of trees, and in the ground. The larva feed voraciously during this stage. Larva of leaf beetles (Chrysomelidae) and weevils feed on leaves, of scarab beetles (Scarabaeidae) feed on roots and decaying vegetative matter in the earth, longhorn beetles (Cerambycidae) and jewel beetles (Buprestidae) mostly feed by burrowing inside tree trunks, ladybird beetle larva (Coccinellidae) feed on aphids, and that of tiger beetles (Cicindelidae) are ambush hunters of ants and other small insects. They form a naked pupa and emerge as adults with fully-formed adult features. Beetles have biting mouthparts, and feed on their preferred food throughout their lifecycle.

Their numbers in India are estimated around 15000 (Kazmi and Ramamurthy 2004), with new species being discovered every year. Most studies in India have been made on specific group of beetles, mostly those impacting human foods such as stored grains. Of the 20 common insect pests in primary and secondary storage pests of India, 12 are beetles (TNAU Agritech Portal n.a.). Beetles are also studied for their role in damaging trees of commercial interest, such as Cerambycidae and Buprestidae (such pestiferous beetles are commonly referred to as stem borers). Role of beetles as indicators of a healthy ecosystem and as important pest controllers in agriculture is also explored, especially of ladybird

beetles (Coccinellidae) and tiger beetles (Cicindelidae). Although studies focusing on diversity of each and every beetle groups of India are far and few and also an ongoing process, it is estimated that the largest diversity of beetles in India is made up by scarab beetles. India is also said to have the largest diversity of tiger beetles.

Coleopteran diversity of Madhya Pradesh is largely unknown. Chandra (2000) had identified 18 species of Scarabaeidae from Balaghat and Mandla of the 94 species from Madhya Pradesh. Chandra and Gupta (2012) have further identified 34 species of *Onthophagus* (Family Scarabaeidae) in Madhya Pradesh, of which 19 species are recorded from Balaghat and Mandla. Considering that a significant portion of both the districts encompasses KTR, and given that the habitats outside the reserve are the same, I assume an equal number of scarab beetles to be occurring within KTR. Further, six species of tiger beetles (Matalin et al 2012; Wiesner 2004) and 5 species of ladybird beetles (Poorani n.a.) are recorded in Madhya Pradesh, however their distribution within the state is not given. A study on longhorn beetles of Chhattisgarh has recorded 10 species (Majumer et al 2014), which are also most likely to be distributed in Madhya Pradesh as well.

In the current study, 49 species were recorded in 18 families, of which 9 remain unidentified but represent their respective families. *Cardiophorus notatus* (13.a) and *Camposternus* sp. (13.d) (Elateridae) are first records for the central Indian region. Together with the number of species occurring in the region from literature, the total species of beetles in KTR is around 85 species, however this small number is a result of few studies on this group in KTR. I guesstimate that Coleoptera is the most diverse order of all animals in KTR, with the real species diversity anywhere above 250 to 300.

This section contains photographs of 48 species of beetles belonging to 17 families recorded in KTR.

Plate 10

10.a. Ladybird Beetle; *Cheilomenes sexmaculata*; Coccinellidae: C

Commonly seen close to Aphid infestations, especially on *Calotropis gigantea*.

10.b. *C. sexmaculata* Larva

Larva of this ladybird beetle are active hunters.

10.c. *C. sexmaculata* Pupa

They pupate on exposed leaves close to Aphid infestations.

10.d. Ladybird Beetle; *Anegleis cardoni*; Coccinellidae: UC

Often seen near Aphid infestations in forested areas.

10.e. Ladybird Beetle; *Sticholotis* cf *ferrugineus*; Coccinellidae: C

Commonly seen near Aphid infestations in forested areas.

10.f. Ladybird Beetle; *Brumoides suturalis*; Coccinellidae: C

Commonly seen near Aphid infestations on *Calotropis gigantea*.

10.g. Ladybird Beetle; *Coccinella transversalis*; Coccindellidae: C

Commonly seen in grasslands than in forested areas.

10.h. Giant Dung Beetle; *Heliocopris* cf *bucephalus*; Scarabaeidae: C

More common during monsoon and post-monsoon months. Visits lights at night. Large beetle. Has a habit of burying itself during daytime in soft soils.

10.i. Dung Beetle; *Onthophagus* cf *orissanus*; Scrabaeidae: UC

Often seen near lights at night. Rolls dung of cattle into small balls and buries them in a burrow. A single egg is laid on the dung upon which the larva feeds.

10.j. Flower Chafer; *Protaeita aurichalcea*; Scarabaeidae: C

Commonly seen during monsoon.

10.k. Flower Chafer; *Anomala* cf *dimidiata*; Scarabaeidae: C

Commonly seen near lights at night during monsoon.

10l. Blister Beetle; *Mylabris pustulata*; Meloidae: C

Commonly seen during monsoon. Contains Cantharidin, a blister-forming chemical, hence the common name. Feeds on leaves and flowers, such as *Ipomea* sp.

10.m. Predacious Diving Beetle; _____; Dytiscidae: C

Aquatic beetle seen commonly close to lake banks and ponds.

10.n. Whirligig Beetle; _____; Gyrinidae: C

Aquatic beetles living in large groups in parts of water covered in shade.

10.o. Ant-like Flower Beetle; _____; Anthicidae: C

Commonly visits lights at night.

Plate 10

Plate 11

11.a. Tiger Beetle; *Calochora flavomaculata*; Cicindelidae: C

Only seen during monsoon. Visits lights at night. Prefers edges of forests.

11.b. Tiger Beetle; *Lophyra* (*Spilodia*) *striolata*; Cicindelidae: C

Only seen during monsoon. Prefers grassland habitat

11.c. Tiger Beetle; *Calochora bicolor haemorrhoidalis*; Cicindelidae: C

Only seen during monsoon. Common during early monsoon months. Prefers open areas in forests. Most common tiger beetle of KTR.

11.d. Tiger Beetle; *Jansenia tetrastacta tetrastacta*; Cicindelidae: C

Only seen during monsoon. Prefers stony paths and grasslands. Contains peculiar two small white spots just above the two prominent ones.

11.e. Tiger Beetle; *Jansenia tetrastacta delhiensis*; Cicindelidae: C

Same as 11.d. Lacks the two small white spots as in 11.d.

11.f. Tiger Beetle; *Cicindela* (*Pancallia*) *princeps*; Cicindelidae: C

Only seen only during monsoon. Prefers forest openings and mud paths. Common during early monsoon months. Largest tiger beetle of KTR.

11.g. Tiger Beetle; *Cicindela* (*Ancylia*) *guttata*; Cicindelidae: C

Prefers grasslands. Common during the "wetter" monsoon. Endemic to India.

11.h. Tiger Beetle; *Myriochila* (*Myriochila*) cf *melancholica*; Cicindelidae: C

Only seen during monsoon. Common throughout monsoon season.

11. i. Tiger Beetle; *Cylindera* (*Ifasina*) *viridilabris*; Cicindelidae: C

Only seen during monsoon. Prefers forest paths. Smallest tiger beetle of KTR.

11.j. Tiger Beetle; *Cylindera foveolata*?; Cicindelidae: UC

Only seen during monsoon. Visits lights at night. Habitat preference unknown.

11.k. Tiger Beetle Larva (head); Cicindelidae

Little burrows measuring around 5mm in diameter built on sloping soft ground. Commonly seen during post-monsoon months; ambush hunters of other insects; only head emerges from the burrow.

11.l. Pleasing Fungus Beetle; cf *Episcapha* sp; Erotylidae: UC

Seen near fresh fungus during monsoon.

11.m. Ground Beetle; Subfamily Odacanthini; Carabidae

Commonly seen in verandah in homes.

11.n. Bombardier Beetle; _____; Carabidae

Nocturnal scavenger; releases a cloud of corrosive fiery chemical when disturbed.

11.o. Chafer Beetle; *Holotrichia serrata*; Scarabaeidae

Visits lights at night. Grubs pest on Sugarcane. Adults feeds on tender Tendu and Saja leaves.

Plate 11

Plate 12

12.a. Round-necked Longhorn Beetle; *Chlorophorus* sp.; Cerambycidae: C

Common during monsoon; visits lights at night.

12.b. Longhorn Beetle; *Calothyrza margaritifera*; Cerambycidae: UC

Seen during monsoon; visits lights at night.

12.c. Sal Borer Beetle; *Hoplocerambyx spinicornis*; Cerambycidae: C

Common during monsoon; visits lights at night. Considered a pest on Sal (*Shorea robusta*) trees. Larvae burrow deep inside the stem and damage the tree.

12.d. Jewel Beetle; *Trachys bicolor*; Buprestidae: C

More common during monsoon than drier months. Feeds on leaves of Tendu (*Diospyros melanoxylon*) and Palash (*Butea monosperma*). Has a habit of collecting its own excrete upon itself for camouflage.

12.e. Jewel Beetle; *Agrilus* sp.; Buprestidae: C

More common during monsoon; small beetle of the most diverse genus group.

12.f. Jewel Beetle; *Psiloptera* sp.; Buprestidae: C

Common during monsoon; large and gaudy beetle seen in forested areas.

12.g. Common Firefly; *Luciola praeusta*; Lampyridae: C

Most common species of Firefly seen in KTR. Common during pre-monsoon months; density reduces as dryness increases.

12.h. Firefly; _____; Lampyridae: C

More common during the wettest part of monsoon.

12.i. Firefly Female; Lampyridae: C

Females of some species of firefly retain their larval form. Active hunters of snails.

12.j. Carpet Beetle Grub; Dermestidae: C

Caterpillars common in homes; feed on natural fibers such as mattresses at homes. Considered as a pest.

12.k. Tortoise Beetle; *Aspidimorpha sanctaecrusis*; Chrysomelidae: C

Common during monsoon. Stays close to its larval host plant *Ipomea carnea*.

12.l. *A. sanctaecrusis* Larva; Chrysomelidae: C

Common during monsoon. Feed voraciously on *Ipomea carnea*, an exotic pest plant common in wetlands in KTR. Covers themselves with excreta for protection.

12.m. *Platypria echidna*; Chrysomelidae: UC

Often seen in dense forests.

12. n. *Dactylispa* sp.; Chrysomelidae: UC

Often seen in dense forests.

12.o. Pumpkin Beetle; *Aulacophora foveicollis*; Chrysomelidae: C

Considered a serious pest on cucurbits grown in farms.

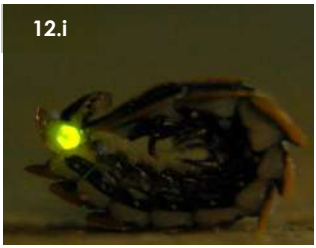


Plate 12

Plate 13

13.a. Click Beetle; *Cardiophorus notatus*; Elateridae: R

Very small beetle. Mimics Velvet Ants (23.a). First record for central India.

13.b. Click Beetle; *Agrypnus fuscipes*; Elateridae: C

Commonly visits lights at night. More common during monsoon months.

13.c. Click Beetle; *Cryptalauss* sp.; Elateridae: UC

Seen during monsoon months.

13.d. Click Beetle; *Camposternus* sp.; Elateridae: UC

Seen during monsoon months. First record for central India.

13.e. Click Beetle; *Lanelater* sp.; Elateridae: C

Commonly visits lights at night during pre-monsoon showers.

13.f. Darkling Beetle; _____; Tenebrionidae: C

Common throughout the year; lives under dense leaf litter. Undergoes "thanatosis" i.e. feigning death when alarmed, as seen in the picture.

13.g. *Cossyphus depressus*; Tenebrionidae: UC

Often seen in dense leaf litter.

13.h. Rove Beetle; _____; Staphylinidae: C

Often visits lights at night. Commonly found near wetlands and marshy areas. Can cause dermatitis if rubbed against skin.

13.i. Weevil; _____; Superfamily Curculiniodea

Curculionoidea is a large superfamily within Coleoptera. This image of an unidentified weevil is used as a representation of this diverse taxa. They typically have a snout, and mostly feed on fresh leaves.

Plate 13

4.2. Note on Sal Borer Beetle (*Hoplocerambyx spinicornis*)

Sal Borer Beetle (*Hoplocerambyx spinicornis*), also called Sal Heartwood Borer (Image 12.c), is one of the largest insects of KTR. Adults can grow as large as 2 to 3 inches, and are commonly observed near light sources during monsoon months. They are widely distributed in Asia (including countries like Burma, Bhutan, China, Indonesia, Malaysia, Nepal, Papua New Guinea, Pakistan, Philippines, Singapore, and Thailand), and infect a number of *Shorea* species (Appanah and Turnbill 1998). In India, they are exclusively found in Sal (*Shorea robusta*) forests and utilize the tree to complete their lifecycle. In comparison to other wood boring beetles, this beetle is said to be the only species that is capable of severely infecting healthy trees (Appanah and Turnbill 1998).

There are several instances of this beetle infecting a large number of Sal trees throughout their geographic range, at times reaching epidemic proportions. Madhya Pradesh, and KTR and its surround areas, have a history of severe Sal infestations, the earliest one documented in 1904 (KTR Management Plan 2001-2010). Sal Borer relies on Sal trees as a larval host plant. Eggs are laid under the bark, from which larva emerge and burrow deep inside to enter the heartwood of the tree, where they feed on the sap. They transform into a pupa inside the tree and emerge as adults after a few pre-monsoon showers (around June-end).

Stringent monitoring protocols have been developed to manage Sal Borer infestations (Singh 2014), and several methods developed to reduce the spread of the infestations. Although a gradual decline in infestations has been observed in KTR, and no infestations of epidemic proportions recorded since 2000, a biological method of controlling Sal Borer is yet to be explored, as is mentioned in KTR's management plan. Since the adults are large and contain a thick exoskeleton, these beetles probably form a part of a diet of very few birds and mammals. Furthermore, although the larvae are soft-bodied, predation is less likely because of their position deep within the tree, where they remain protected from external factors. The only significant biological control (bio-control) of Sal Borer appears to be parasitism by parasitoid insects.

Bio-control of insect pests is one of the most efficient ways of pest control, especially when the predatory or parasitic species exist naturally within the distribution range of the pest. For instance, native ladybird beetles are used in fields to control aphid populations via predation; several Chalcid, Braconid and Ichneumon wasps are known as controllers of the Emerald Ash Borer beetle

(*Agrilus planipennis*) in North America and *Monochamus* sp. in Europe via parasitism.

Studies on parasitism on Sal Borer need to be explored, since bio-control of this beetle, in addition to manual management practices, will be a more efficient and long-term solution to the periodic problem of Sal infections. As a primer to explore prasitoids on Sal Borer, a rapid assessment of Sal infestations was undertaken using line transect method in five beats of Mukki Range to identify Sal trees infected by Sal Borer infestations. Infected trees are fairly easy to identify by the presence of a heap of sawdust-like powdered Sal wood at the base of the tree. Trees were classified into two groups: dead because of Sal Borer infestation, and alive but infected. Quadrats were laid near such trees to identify presence of any parasitoids that could potentially parasitize upon Sal Borer.

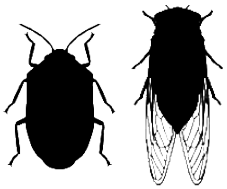
Members of the family Tachinidae (Order Diptera) and Ichneumonidae (Order Hymenoptera) were encountered in quadrats near infected trees. Although this does not signify that they parasitize on Sal Borer, members of these families, in addition to Chalcidae and Braconidae (Order Hymenoptera), are known to parasitize on Cerambycid beetles. Studies that focus on parasitoids of Sal Borer are however lacking, and can be a focus for future management of this beetle.

One of the important points to note is that Sal Borer is an indigenous beetle and has coevolved to depend upon Sal trees for its growth. Since Sal trees, although slow in growth, are gregarious in habit and form pure crops by inhibiting the growth of other trees around, Sal Borer appears to be the only recorded species capable of clearing weak Sal trees and making room for young ones. The badge as a pest species is owing to the commercial value of Sal trees.

Having said that, management of Sal Borer to avoid epidemics is crucial to maintain a balance in this depleting ecosystem upon which a number of other animals, including the tiger, depend. The KTR management plan records that infestations are more in Sal trees that are stressed due to anthropogenic activities of lopping, land clearing, and grazing, which can potentially increase the infestation to epidemic proportions. Exploring the role of indigenous parasitoids of Sal Borer by identifying them on the field, and rearing them in laboratories for their services in controlling Sal Borer populations, will help reduce the problem significantly.

5. Hemiptera

Hemi = half; *ptera* = wings



Hemiptera encompasses insects commonly termed as "true bugs". These insects are typically shield-shaped, having a broad thorax and a tapering abdomen. Their head is generally triangular, ending into a blunt tip, or is cylindrical. They have two pairs of wings, in most species the forewings are hardened half-way at the base, and cover the hindwings which are used in flight. They possess a sharp needle-like mouth which helps them pierce their preferred food source, including leaves, stems, and tree trunks, as well as to capture and feed on prey.

They do not undergo metamorphosis like butterflies and beetles, but are hemimetabolous (undergo incomplete metamorphosis). Adults lay eggs on any natural or manmade surface, from which small nymphs emerge that resemble adults but lack wings. They usually feed on the same food source the adults do, and grow by periodically moulting the exoskeleton. The matured stage have fully developed wings covering their abdomen. Members of this order are commonly called shield bugs, stink bugs, and assassin bugs.

This order also comprises of members of the former suborder Homoptera, now split into Sternorrhyncha, Auchenorrhuncha, and Coleorrhyncha, including aphids, scale insects, cicadas, leaf and treehoppers, which are morphologically different from the true bugs, but possess sucking mouthparts. Their larva may or may not resemble the adult forms, however follow the same hemimetabolous lifecycle.

Knowing this order is important in economic terms, since several species are considered pests on standing crop, and one in particular, the bedbug, is an ectoparasite on humans, which feeds on blood.

Several species of Hemiptera, commonly called Lac insect (most popular is *Kerria lacca*), are of great economic value. These insects feed on several tree species, and produce a sticky resinous substance called lac, which is used in the production of shellac and dyes. India is a major producer of lac, contributing over 60% of world's lac demand. Several Indian states produce lac, of which Chhattisgarh is the largest producer (Paul, Kumar and Das 2013). Madhya Pradesh also produces lac, and there are several Eco-Development Committee (EDC)-run and private forest lands which produce lac in KTR. Raw lac is sold for a

minimum sum of Rs. 100 per kilogram (maximum up to Rs. 300 per kilogram), generating a considerable amount of income for the owner. This order however is one of the few (the others being Coleoptera, Diptera, and Orthoptera) that are known more for their pestiferous insects than beneficial ones.

An estimated 50000 to 80000 species of Hemiptera are said to exist in the world, and over 6500 are found in India, of which 2421 are endemic (Kumar and Naidu 2010). Extensive studies have been undertaken on this order in Madhya Pradesh, and about 161 species are recorded from the state (Chandra, Bhandari and Kushwaha 2015; Chandra *et al* 2014; Chandra and Kushwaha 2014; Chandra *et al* 2012; Chandra *et al* 2012b). Studies focusing on KTR are almost none, except for a record of 14 species by Chandra *et al* (2012) in Mandla.

In the current study, 47 species belonging to 32 families have been recorded, of which 10 have been identified only up to family-level. This section contains photographs of these bugs recorded in KTR.

Plate 14

14.a. Aphid; *Aphis nerii*; Aphididae: C

Small. Considered a pest on a number of commercial crops; females flightless.

14.b. Mealybug; *Icerya* sp.?; Pseudococcidae: C

Considered a pest on a number of commercial crops; females flightless. Modified body-parts to live a largely sedentary life. Nymphs are mobile.

14.c. Lantern Bug Nymph; Fulgoridae: C

Common in forested areas; lives on sap of plants. Adults are winged.

14.d. *Dichoptera* sp.; Fulgoridae: C

Common near lights.

14.e. *Pyrilla* cf *perpusilla*; Lophopidae: C

Considered a pest on crops such as maize.

14.f. Lantern Fly; _____; Dictyopharidae: C

Also called Lantern Bugs because of the extended snout. Common near lights.

14.g. Rabbit-eared Bug; _____; Derbidae: C

Common on Palm trees. Can be pestiferous in large numbers. Feed on leaf sap.

14.h. Spittle Bug Adult; _____; Aphrophoridae: C

Common throughout the year. Also called Leafhoppers.

14.i. Spittle Bug Nymph Retreat; _____; Aphrophoridae: C

Only seen during wet season. This sticky retreat is built at the base of a leaf or on a tender green stem. Most commonly observed on Saja (*Terminalia tomentosa*).

14.j. Cicada; *Platypleura basialba*; Cicadidae: C

Most commonly heard in the day during summer. Often get attracted to lights.

14.k. Cicada Nymph Moult; Cicadidae: C

Nymphal lifespan is longer than adult. Exclusively live underground feeding on root sap of trees. Emerge from the ground to metamorphose into adults.

14.l. *Heteropsylla* sp.; Psyllidae: C

More common when Tendu sprouts new leaves. Feed on leaf sap. Can invade a Tendu tree and damage young leaves.

14.m. *Pochazia* cf *atkinsoni*; Ricaniidae: C

Commonly seen in shrubs.

14.n. Flatid Hopper; _____; Flatidae: C

Commonly seen feeding on tree sap.

14.o. Lac Insect; *Kerria lacca*; Kerriidae: C

Not seen in natural ecosystem of KTR. Introduced for commercial production of Lac on Palash (*Butea monosperma*).

Plate 14

Pate 15

15.a. Stink Bug; *Erthesina fullo*; Pentatomidae: C
Commonly seen near lights; ejects a pungent liquid when threatened.

15.b. Shield Bug; *Tolumnia* sp.; Pentatomidae: UC
More common in forested areas. Also ejects a pungent liquid when threatened.

15.c. Shield Bug; *Carbula scutellata*; Pentatomidae: C
Commonly seen feeding on herbs during monsoon.

15.d. Painted Bug; *Bagrada hilaris*; Pentatomidae: C
Common in vegetable gardens than in the wild. Pest on Cucurbit plantations.

15.e. Broad-headed Bug; *Riptortus linearis*; Alydidae: C
Common during monsoon. Often found in undergrowth of forests.

15.f. Rice Bug; *Leptocorisa oratorius*; Alydidae: C
Common in forested areas. A pest on Rice.

15.g. Assassin Bug; *Euagoras plagiatus*; Reduviidae: C
Carnivorous; feeds on other insects.

15.h. Assassin Bug; *Acanthaspsis luteipes*; Reduviidae: C
Carnivorous; feeds on other insects.

15.i. Assassin Bug; *Ectrychotes dispar*; Reduviidae: C

15.j. Assassin Bug; *Oncocephalus* sp.; Reduviidae: C
Carnivorous; feeds on other insects.

15.k. Assassin Bug: *Polididus* sp.; Reduviidae: C
Carnivorous; feeds on other insects.

15.l. Rice Leafhopper; *Nephotettix virescens*; Cicadellidae: C
Commonly visits lights at night. Considered a pest on Rice.

15.m. Red Silk Cotton Bug; *Dysdercus* sp.; Pyrrhoccoridae: C
Common throughout the year. More common near Semal (*Bombax ceiba*) and Kusum (*Schleichera oleosa*) trees in the forests. Feed on fruit and seed sap.

15. n. Red Silk Cotton Bug Nymph; *Dysdercus* sp.; Pyrrhoccoridae: C
Dysdercus usually live together in a community mixed with nymphs of varying stages of development and adults.

15.o. Crusader Bug; *Graptostethus servus*; Lygaeidae: C
Common on *Calotropis gigantea*.

Plate 15

Plate 16

16.a. Jewel Bug; *Chrysocoris stolli*; Scutelleridae: UC

Often seen on or near Jatropha plantations. Adults resemble beetles but have sucking mouthparts.

16.b. *Hotea nigrorufa*; Scutelleridae: C

Small in size. Almost always seen on *Urena lobata* shrub.

16.c. Thread-legged Bug; *Metacanthus pulchellus*; Berytidae: UC

Often seen perched on the surface of leaves. Extremely long, slender legs; feeds on plant sap.

16.d. Leaf-footed Bug; *Cletus punctiger;* Coreidae: C

Commonly seen in gardens; gets attracted to lights at night.

16.e. Leaf-footed Bug; *Clavigralla gibbosa*; Coreidae: C

Commonly seen on *Calotropis gigantea*. Considered a pest on leguminous plants.

16.f. Leaf-footed Bug; *Dalader planiventris*; Coreidae: C

Commonly seen in forest clearings on herbs.

16.g. Leaf-footed Bug; *Anoplocnemis plasiana*; Coreidae: C

Commonly seen in forested areas.

16.h. Horned Tree Hopper; *Otinotus oneratus*; Membracidae: C

Commonly seen feeding on a number of trees including Sal (*Shorea robusta*), and other commercial fruiting trees.

16.i. Lace Bug; *Stephanitis typica*; Tingidae: C

Considered a pest on Banana trees.

16.j. Leaf Bug; *Lygus* sp.; Miridae: C

Common in gardens and farms.

16.k. Leaf Bug; _____; Miridae: C

Commonly seen in forested areas. Observed feeding on *Urena lobata* shrub.

16.l. Froghopper; *Callitettix versicolour*; Cercopidae: C

Mostly seen during monsoon. Nymphs also build a spit-like retreat. Adults feed on grasses.

16.m. Long-necked Bug; _____; cf Rhyparochromidae: UC

Seen in Sal forest, exclusively with thick leaf litter.

16.n. Backswimmer; *Anisops* sp.; Notonectidae: C

Aquatic. Swims upside down at the surface of still waterbodies.

16.o. Water Boatman; *Corixa* sp.; Corixidae: C

Aquatic. Swims underneath the water in shallow regions, especially near the banks of still waterbodies.


16.a


16.b


16.c


16.d


16.e


16.f


16.g


16.h


16.i


16.j


16.k


16.l


16.m


16.n


16.o

Plate 16

Plate 17

17.a. Giant Water Bug; *Lethocerus indicus*; Belostomatidae: C

Aquatic. Largest insect of KTR. Remains at the surface of still waters such as lakes and ponds. Predatory. Often gets attracted to light at night.

17.b. Water Strider; _____; Gerridae: C

Often seen skating on the surface of water. Predatory and scavenger in nature.

17.c. Water Scorpion; _____; Nepidae: C

Aquatic. Remains still underwater on aquatic plants or on stones. Predatory.

17.d. Water Measurer; _____; Hydrometridae: C

Aquatic. Remains along the edge of wetlands; can walk on water; scavenger.

17.e. Bedbug; *Cimex lectularius*; Cimicidae: C

Ectoparasite of mammals, especially humans. Feeds on blood. Considered an indoor pest. Not found in natural ecosystems of KTR.

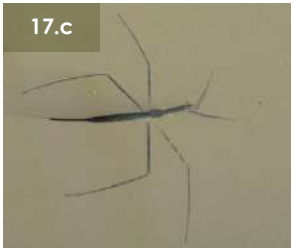
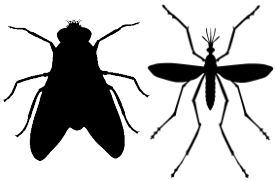


Plate 17

6. Diptera



Di = two; *ptera* = wings

Diptera is an order of "true flies", distinguished from other insects with a suffix "fly" in them (such as dragonfly and damselfly which belong to order Odonata, and firefly which belongs to Coleoptera), by the observance of only one pair of wings unlike other insects. In case of true flies, the second pair of wing is modified into minute, club-shaped structures called halterers which aid the flies in their aerodynamic maneuvering. The members of this order are generally divided into two suborders. Brachycera consists of the typical flies with a rounded head, a squarish thorax, and an oval or elongated abdomen and wings that are usually kept half closed over the abdomen when at rest. The common members of Brachycera include the Housefly, Flesh fly, and Robber fly. Suborder Nematocera comprises of members who usually are small in size, with a small head, scaly covering over the body, and feathered antennae, and includes members such as mosquitoes, midges, and gnats.

The flies undergo complete metamorphosis. Females usually lay eggs near their preferred food; either in rotting flesh, external wounds, plants (in stems, leaves, and fruits), damp litter, wetlands, and some are parasitic in nature. Larvae of flies are called maggots; they are legless and walk by creeping. Larva of Brachyceran flies usually live in terrestrial ecosystems, whereas those of Nematocera largely live an aquatic life. They feed voraciously on the food source, and moult as they grow in size until they form a pupa. An adult fly usually lives for around a month. Most adults feed by lapping method, while ectoparasitic flies such as mosquito and horsefly have razor-sharp mandibles which cut through flesh to feed on blood.

Flies are of utmost ecological importance as they are of economic. Several species, such as Flower fly *Lathyrophthalmus* sp., Bluebottle fly *Chrysomya* sp., and members of Bombyliidae and Culicidae visit flowers of fruiting trees such as Jamun (*Syzygium cumini*) and a number of flowering herbs in KTR. Fly maggots (probably belonging to Tephritidae) are commonly found in Mahua (*Madhuca indica*) flowers where they feed on the corolla and potentially help pollinate the flowers. Flies are probably only next to bees and wasps in terms of their importance in pollination. A number of maggots are responsible for degradation of organic matter in the forest floor, enabling nutrient recycling and increasing

the richness of the soil – a feat achieved by very few groups of insects such as beetles. Some are strictly predatory in nature (family Asilidae), preying on pestiferous insects such as mosquitoes (also in the order Diptera), and help in controlling populations of other insects. As many as 555 species of flowering plants are said to be visited by flies (Oxford, Vaughan and Memmott 2015) – increasing the chances of their pollination. Some such as Tachinidae and Sarcophagidae are parasitoids on pestiferous insects such as woodborers (Coleoptera), moths (Lepidoptera), and grasshoppers (Orthoptera). However, these ecosystem services of flies are not explored in monetary terms, making them one of the most ignored groups of organisms on our planet.

Economically, flies are considered serious pests for two reasons; for damaging food and spreading diseases. They damage standing and stored vegetables, the prominent examples of which are Fruit flies (family Tephritidae, Drosophilidae, and Phoridae), as well as damage stored meat (family Sarcophagidae). In terms of health concerns, the most infamous are mosquitoes (family Culicidae). Studies have shown that the region is experiencing perennial malaria transmission. A study has reported >80% cases from *Plasmodium falciparum*, with >30% infections found in infants under 6 months of age in regions of Balaghat District (Singh *et al* 2013). Flies (family Muscidae and Sarcophagidae) are also a nuisance for livestock owners, since they infect open wounds on animals, causing necrosis and leading to other diseases. Horseflies (family Tabanidae) are also present in KTR, females of which feed on blood, and give a painful bite which leads to itching. The tiny wound can later get infected on repeated scratching.

Diptera thus encompasses a diversity that affects us directly – either in good or bad ways. Over 150000 species of Diptera are recognised (Thompson 2008) in about 171 families (137 Brachycera and 34 Nematocera), containing nearly a worldwide distribution. In India, an estimated 85 Diptera families have been recorded (Mitra *et al* 2015), however the species diversity in India is uncertain. Studies have focused more on groups of flies pestiferous in nature, such as mosquitoes and fruit flies. Diptera of Madhya Pradesh is largely unknown. Mitra *et al* (2015b) recorded 19 species of Syrphidae from Madhya Pradesh. A study by Patel *et al* (2015) in a community reserve in Madhya Pradesh revealed 78 numbers of flies in 20 families.

In the current study, 40 species have been recorded in 32 families (25 Brachycera and 7 Nematocera) from KTR, of which 17 species remain unidentified since it is difficult to identify Diptera based on photographs. This section provides photographs of Diptera of KTR along with notes on their ecology.

Plate 18

18.a. Housefly; *Musca domestica*; Muscidae: C

Common in human settlements.

18.b. Flesh fly; *Sarcophaga* sp.; Sarcophagidae: C

Common in human settlements, near organic garbage. Lays eggs in carcass.

18.c. Bluebottle fly; *Chrysomya* sp.; Calliphoridae: C

Common in human settlements near organic garbage. Lays eggs in carcass. Commonly seen on carcass of wild animals. Rests in crevasses in large numbers.

18.d. *Bengalia* sp.; Calliphoridae: C

Kleptoparasitic (feeds on food captured by another organism) in nature; steals foodstuff carried by ants; also feeds on ant pupa. Usually seen perched on the ground close to ant trails.

18.e. *Stomorhina* sp.; Calliphoridae: C

Often seen visiting flowers for nectar. Species in this genus are important egg-predators of locusts.

18.f. Anthomyid fly; *Anthomyia* sp.; Anthomyiidae: C

Common in forested areas. Larva feed on roots of vegetables such as cabbage.

18.g. Hoverfly; *Episyrphus* sp.; Syrphidae: C

Commonly seen near flowers; adults feed on nectar; help pollinate several herbs.

18.h. Hoverfly maggot; *Episyrphus* sp; Syrphidae: C

Larvae are predatory; feed on aphids. Important bio-controllers of aphid infestations in agriculture.

18.i. Flower fly; *Lathyrophthalmus* sp.; Syrphidae: C

Often seen visiting flowers; potential pollinator of several trees and herbs.

18.j. Tachinid fly; cf *Cordyligaster* sp.; Tachinidae: C

Often seen perched on leaves or tree trunks. Parasitoid of Lepidoptera.

18.k. Tachinid fly; _____; Tachinidae: C

Commonly seen perched on leaves.

18.l. Tachinid fly; *Mikia tepens*; Tachinidae: R

Observed only once. Known to parasitize on congregating Lepidoptera caterpillars, especially pine caterpillars.

18.m. Black Soldier fly; *Hermentia illucens*; Stratiomyidae: C

Adults visit flowers; larva feed on detritus; larva also used in biocomposting.

18.n. Eye fly; _____; Chloropidae: C

Often fly close to face and enter eyes for water. Rest in congregations in shade.

18.o. Bee fly; _____; Bombyliidae: C

Large, bee-like flies; adults are flower visitors.

Plate 18

Plate 19

19.a. Robber fly; *Neoitamus* sp.; Asilidae: C

Active predators; larva live in organic-rich soil and rotting wood.

19.b. Stilt legged fly; _____; Micropezidae: C

Common near dense and moist places; often seen perched on leaves.

19.c. Banana stalk fly; *Telostylinus* sp.; Neriidae: UC

Seen in small groups on tree trunks; feed on sap of rotting fruits. Larva feed in rotting fruits and other vegetation.

19.d. Horsefly; *Tabanus* cf *melanocerus*; Tabanidae: C

Females feed on blood of mammals, including humans. Males visit flowers.

19.e. Horsefly; *Chrysops* sp.; Tabanidae: C

Females feed on blood of mammals, including humans. Males visit flowers.

19.f. Horsefly; *Hematopota* sp.; Tabanidae: C

Females feed on blood of mammals, including humans. Males visit flowers.

19.g. Fruit fly; *Bactrocera* sp.; Tephritidae: C

Considered pests on cucurbits. Adults often found in vegetable gardens. Larvae feed inside the fruit.

19.h. Fruit fly; cf *Bactrocera* sp.; Tephritidae: C

This particular species was found inside the forest; not seen in vegetable gardens.

19.i. Fruit fly; *Platensina* sp.; Tephritidae: C

Common in vegetable gardens. Pest on several fruiting plants.

19.j. Long legged fly; *Chrysosoma* sp.; Dolichopodidae: C

Commonly seen perched on leaves; active predators.

19.k. Common fruit fly; *Drosophila* sp.; Drosophilidae: C

Commonly seen near organic garbage sites (especially kitchens).

19.l. Dung fly; _____; Sepsidae: C

Commonly observed in forests on dung. Larva help in nutrient recycling of dung.

19.m. Picture winged fly; *Physiophora* sp.; Ulidiidae: C

Common in dense and moist places; occasionally near garbage.

19.n. Snail-killing fly; *Sepedon spinipes*; Sciomyzidae: C

Common near marshy areas; larva feed on snails. Are considered potential biocontrollers of snails for liver fluke parasites.

19.o. Scuttle fly/Kleptoparasitic fly; _____; Phoridae: C

Pictures member common in forested areas; kleptoparasite in nature; feeds on prey captured by spiders. Other members are commonly found near organic garbage or near open wounds of animals.

Plate 19

Plate 20

20.a. Beetle fly; _____; Celyphidae: C

Commonly seen in moist places, usually near a wetland. Larvae feed on detritus.

20.b. Stalk-eyed fly; *Teleopsis* sp.; Diopsidae: UC

Common near moist places, near densely wooded wetlands. Indicators of good ecosystem health of wetlands.

20.c. Stalk-eyed fly; *Sphyracephala* sp.; Diopsidae: UC

Common near moist places, usually in association with *Teleopsis* sp. Indicators of good ecosystem health of wetlands.

20.d. Mantis fly; *Ochthera* sp.; Ephydridae: UC

Active hunters; feed on other small insects. Larvae are known to prey on mosquito larva; while adults are known to prey on adult mosquitoes. Considered an important predator of malaria vectors in Africa.

20.e. Louse fly; *Pseudolychia* sp.; Hippoboscidae: C

Ectoparasite on birds, especially common in pigeons. Feeds on blood. Members of this family are also known to be parasites on mammals.

20.f. Lauxanid fly; _____; Lauxaniidae: C

Commonly seen perched on leaves near forest paths; larvae feed on organic detritus in dense forest litter.

20.g. Mosquito; *Aedes* sp.; Culicidae: C

Common. *Anopheles* sp., and *Culex* sp., are also common in KTR. Feed on blood of mammals and birds. *Anopheles culicifacies* is a known vector of malaria in KTR.

20.h. Non-biting midge; *Chironomus* sp.; Chironomidae: C

Commonly seen near lights throughout the year. Adults resemble mosquitoes but lack the elongated mandibles and have a downward-pointing head. Harmless. Larva are aquatic; serve as indicators of good wetland ecosystem health.

20.i. Cranefly; _____; Tipulidae: C

Resemble mosquitoes, but have extremely long legs; harmless; larva are aquatic.

20.j. Mango Gall Midge; *Procontarinia* sp.; Cecidomyiidae: C

Galls appear as round balls on the underside of Mango (*Mangifera indica*) leaves.

20.k. Gnat; _____; Cecidomyiidae: C

Adults found in congregations; Larva form galls on leaves and stems.

20.l. Dark-winged fungus gnat; _____; Sciaridae: C

Associated with fungus; common in moist areas.

20.m. March fly; _____; Bibionidae: C

Short-lived adults common during monsoon; larva feed on vegetative matter.

20.n. Moth fly; *Clogmia* sp.; Psychodidae: C

Common in moist places in human habitations, such as kitchen and bathroom.

Plate 20

7. Hymenoptera

Humen = membrane; *ptera* = wings

Hymenoptera is a diverse family encompassing wasps, bees, ants, and sawflies. This order is one of the largest, constituting 8% of all described species (Davis, Baldauf and Mayhew 2010). Most, if not all, are flower visitors, and their larval life is either dependent on pollen and nectar, or on other insects and spiders. This group is best known for its social behaviour. Morphologically these insects typically have two pairs of wings which appear jointed. The hindwings have a series of hooks (called hamuli) connecting to the forewings; two types of antennae are mainly seen in this group, filiform, where the antennae are straight and many-segmented, each segment more-or-less of the same length, and geniculate, which are elbowed. The lifecycle of all hymenopterans is holometabolous. They undergo complete metamorphosis.

Further up the evolutionary tree, two distinct suborders are recognised. Symphyta encompasses Sawflies, and Apocrita encompasses wasps, bees, and ants. Sawflies are robust-built, small insects whose larvae appear similar to the caterpillars of Lepidoptera. They feed on plants and are considered pests on several commercial plants, however Sawflies were not recorded in KTR in the present study. Apocrita is distinguished by the constriction between the abdomen and the thorax, giving them a narrow waist called petiole. Their larvae (called grubs) do not have legs, and live a sedentary life dependent completely upon the food provided by adults. Many members of this group are flower-visitors, feeding on nectar and pollen, and several of these hunt other insects and spiders to feed their young. In some Apocrita, the ovipositor (a female egg-laying organ present at the tip of the abdomen), is modified into a stinger with venom glands. The sting is generally used to envenom and paralyze a food resource (such as caterpillars, grasshoppers, and spiders), but is also used solely for defense, such as in honeybees.

Ants are a unique member of this group, with only fertile males and females (Drones and Queens, respectively), having wings for nuptial flight. The majority of the members, including workers and soldiers, are wingless. A group of wasps in the family Mutillidae contain wingless females which resemble ants (hence are called Velvet Ants), but are easily distinguished by the absence of a prominent

petiole and presence of dense pelt of hair-like structures covering the entire body.

Many of the members of Apocrita are important pollinators and biological pest controllers. While pollinators such as Indian Honeybee, Stingless bee, and Potter Wasps are well known, this suborder is also known for its predators and parasitoids targeting several pest species, including moths, beetles, and true bugs; and are also population controllers of other predatory arthropods such as spiders. Use of hymenopterans in biological pest control is a popular research topic amongst entomologists, and has proved as an effective way of preventing pest outbreaks without the use of harmful pesticides. Studies have shown wasp parasitoids of woodborer beetles to be very important management strategy to control their populations (*see chapter 4.2*).

Although 150000 species are said to have been identified worldwide so far, records state that ants comprise of 25000, wasps 20000 to 30000, and sawflies 8000 species. The number of species of Hymenoptera is largely unknown. In India, 652 species of ants (Bharti 2011) have been recorded. Literature on other hymenopterans is scattered geographically. In the central Indian landscape, eight species of Sphecid wasps have been identified from Nagpur city (Deshmukh 2015), five species from Mandla district (Shrivastava n.a.), eleven families from a forest reserve in Mandla (Patel *et al* 2015), and two species of Mutillids from Madhya Pradesh (Chandran and Dey 2013). Gangrade (1964) had studied the biology of *Campoletis perdistinctus* (Ichneumonidae), a parasitoid of *Heliothis armigera* (a pestiferous moth), in Madhya Pradesh. Furthermore, there are several records of individual species in various families from Madhya Pradesh, such as Trichogrammatidae.

In the present study, 77 members belonging to 22 families have been documented; of which 25 members remain identified only up till Family-level, and 52 up to genus/species level. The most documented diversity is made up by Formicidae, followed by Mutillidae, Vespidae and Apidae. This section focuses on ecology of 77 members of Hymenoptera of KTR.

Plate 21

21.a. *Camponotus compressus*; Formicidae: C

Commonly seen in disturbed habitats and human settlements. Often seen tending to Hempitera bugs and scavenging.

21.b. *Camponotus sericeus*; Formicidae: C

Smaller than *C. compressus;* more common in leaf litter in all vegetation types. Scavenging and hunting in habit.

21.c. Black Crazy Ant; *Paratrachina longicornis*; Formicidae: C

Small ants commonly seen near human habitations. Scavenger in habit.

21.d. *Polyrhachis* sp.; Formicidae: C

Common on trees; distinguished from *C. sericeus* by the presence of spines on thorax and petiole. Tends to Hempitera bugs and scavenging in habit.

21.e. Weaver Ant; *Oecophylla smargdina*; Formicidae: C

Found in all vegetation types. Hunting and scavenging in nature.

21.f. White-footed ghost ant; *Technomyrmex albipes*; Formicidae

Very small ant, commonly nests in abandoned tunnels and burrows of termites.

21.g. *Crematogaster* sp.; Formicidae: UC

This dark member of Crematogaster genus was seen only once. Fast, strictly arboreal ant but often comes down on the ground to hunt or scavenge.

21.h. *Crematogaster* sp. nest; Formicidae

Nest of Crematogaster sp. (21.g) is made up of pulp of wood on a tree.

21.i. *Crematogaster* sp.; Formicidae: C

Most common member of Crematogaster genus. Nests in holes in a tree. Hunting, scavenging in nature, also tends to Hemiptera bugs.

21.j. *Meranoplus bicolor*; Formicidae: C

More common in clear grounds, occasionally seen in leaf litter. Small ant building nest underground. Nest opening is usually a small hole.

21.k. Harvester Ant; *Monomorium criniceps*; Formicidae: C

Common near farms; harvests grass grains. Major worker shown in the image.

21.l. Harvester Ant nest entrance; Formicidae

Nests surrounded by husk of rice grains, which is the typical identity of this ant.

21.m. *Monomorium pharaonis*; Formicidae: C

Common near human habitations; scavenging in habit. Nests in crevasses.

21.n. *Pheidole* cf *watsoni*; Formicidae: C

Common near farms; harvests grass grains and scavenges on insects.

21.o. *Pheidole* nest entrance; Formicidae

Nest typically riddled with parts of other insects, especially of *Camponotus* ants.

Plate 21

Plate 22

22.a. *Myrmicaria brunnea*; Formicidae: C

Commonly seen in moist parts of the forest.

22.b. *M. brunnea* nest entrance; Formicidae

Nest is underground, typically built in soft soil. Entrance has several openings surrounded by dug-up soil arranged in a curve.

22.c. Arboreal Bicolour Ant; *Tetraponera rufonigra*; Formicidae: C

Live on trees, seen foraging on tree trunks. Hunting and scavenging in habit.

22. d. *Diacamma ceylonese*; Formicidae: UC

Seen in dense litter of moist forests. Nests under leaf litter or rocks.

22.e. Procession Ant; *Leptogenys processionalis;* Formicidae: C

Commonly seen walking in long trails. Hunting in groups. Probably the most painful sting of KTR's ants.

22.f. *Leptogenys chinensis*; Formicidae: UC

Seen in moist places; forages solitarily unlike *L. processionalis*. Hunting in habit.

22.g. *Solenopsis geminata*; Formicidae: C

Known from urban areas; found in mixed deciduous forest under a rock in KTR.

22.h. *Tapinoma melanocephalum*; Formicidae: C

Commonly seen in kitchens, small ant inhabiting all vegetation types in KTR.

22.i. *Pachycondyla luteipes*; Formicidae: C

Common in marshy areas.

22.j. *Dorylus* cf *labiatus*; Formicidae: R

Dwells underground. Workers are blind. Rarely surface to forage on fallen fruits.

22.k. *Dorylus* cf *labiatus* Male; Formicidae: C

Males commonly attracted to lights especially during monsoon. Exceptionally large in size (>1inch) compared to workers (<1cm).

22.l. Army ant; *Aenictus* sp.; Formicidae: R

Documented only once in a dense mix deciduous forest in Samnapur range. Walk in a single row, nest in rocky crevasses, some ants usually stand guard on ant trails.

22.m. Velvet Ant; Mutillidae: C

Ant-like wasps; Velvet Ants are wasps in the famil Mutillidae. Females are wingless. Images 22.m to 23.k represent different members of Mutillidae documented in KTR. Found in all habitat types, mostly seen on ground and not in canopy. Parasitoids of a number of other wasps, flies, and beetles. Males are winged (23.l).

22.n. Velvet Ant; Mutillidae: C

22.o. Velvet Ant; Mutillidae: C

Plate 22

Plate 23

23.a. Velvet Ant; Mutillidae: C

23.b. Velvet Ant; Mutillidae: C

23.c. Velvet Ant; Mutillidae: C

23.d. Velvet Ant; Mutillidae: C

23.e. Velvet Ant; Mutillidae: C

23.f. Velvet Ant; Mutillidae: C

23.g. Velvet Ant; Mutillidae: C

23.h. Velvet Ant; Mutillidae: C

23.i. Velvet Ant; Mutillidae: C

23.j. Velvet Ant Male; Mutillidae: C

Male mutillids are winged, and often larger in size than females.

23.k. Velvet Ant; Myrmosidae: C

Myrmosidae was formerly a subfamily under Mutillidae.

23.l. *Methocha* sp.; Tiphiidae: R

Wingless ant-like female wasp. Parasitoid of Tiger Beetles. Prefers forest floor where Tiger Beetle grubs are found. More common during late-summer and early-monsoon months.

23.m. *Trypoxylon* sp.; Crabronidae: C

Commonly seen around settlements wherever wooden structures are present. Nest in a pre-existing hole in deadwood. Preys on spiders of *Tetragnatha* genus.

23.n. *Cerceris* sp.; Crabronidae: UC

Seen visiting flowers.

23.o. Sand wasp; _____; Crabronidae: C

Nest in sands along banks of ponds, streams, and rivers.

Plate 23

Plate 24

24.a. *Xenorhynchium nitidulum*; Vespidae: C

Commonly seen in gardens. Observed feeding on *Calotropis gigantea* flowers.

24.b. *X. nitidulum* nest; Vespidae

Nest of is made up of mud coated with tree resin. Each cell resembles a basket. Start nest construction in summer (May) until June.

24.c. *Rhynchiium* cf *sibilans*; Vespidae: UC

Seen visiting flowers. A dead specimen was found near lights.

24.d. Paper wasp; *Ropalidia brevita*; Vespidae: C

Most common Paper wasp of KTR; makes small open nests from wood pulp.

24.e. Paper wasp; *Ropalidia marginata*; Vespidae: UC

Larger than R. brevita; build larger nests. Grubs are fed with caterpillars which are broken in pieces and minced using mandibles.

24.f. Tropical hornet; *Vespa tropica*; Vespidae: C

Prey upon paper wasps (esp. *R. brevita*). Commonly seen flying solitary.

24.g. Potter wasp; *Delta conoideum*; Vespidae: C

Most common paper wasp of KTR. Feeds on pollen and nectar.

24.h. *D. conoideum* nest; Vespidae

Nest is typically pot-shaped, hence the common name. Pots are cells where a single egg is laid, and is stacked with paralyzed caterpillars. In presence of an abundance of prey, multiple pots are built side-by-side.

24.i. Potter wasp; *Delta dimidiatipenne*; Vespidae: UC

Same in habit as *D. conoideum*. Builds pot-shaped nest; albeit less in numbers.

24.j. Potter wasp; *Delta esuriens*; Vespidae: UC

More common in forests than other *Delta* species. Similar in habit as other species.

24.k. Potter wasp; *Phimenes flavopictum*; Vespidae: C

More common in forests, especially near slow-flowing streams.

24.l. Potter wasp; *Ancistrocerus* sp.; Subfamily Eumeninae; Vespidae: C

Common in gardens, although not frequently observed due to small size.

24.m. Potter wasp; *Antepipona* sp.; Subfamily Eumeninae; Vespidae: C

Common near human buildings; make small, irregular tubes of mud on walls.

24.n. Potter wasp; *Antepipona* cf sibilans; Subfamily Eumeninae; Vespidae: C

Another member of Eumeninae, makes small burrow in deadwood.

24.o. Potter wasp; *Antepipona* sp.; Subfamily Eumeninae; Vespidae: C

More commonly seen roosting at night in small numbers.

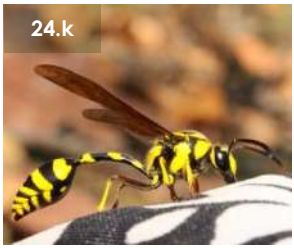


Plate 24

Plate 25

25.a. Braconid wasp; cf *Iphiaulax* sp.; Braconidae: C

Especially common during early monsoon. Known parasitoid on a number of wood boring beetles. Emergence of adults coincides with emergence of adult longhorn beetles during pre-monsoon showers.

25.b. Unidentified; _____; Braconidae: C

Very small in size (<1cm); common at lights in the night during monsoon.

25.c. Ichneumon wasp; _____; Ichneumonidae: C

Commonly seen in gardens and forest floor potentially looking for a host species.

25.d. *Xanthopimpla* sp.; Ichneumonidae: C

Seen exploring herbs, flies close to ground. More common in bushes in marshy areas. Parasitoid of stem borers in the order Lepidoptera.

25.e. *Ischnojoppa luteator*; Ichneumonidae: C

More common in bushes in marshy areas. Parasitoid of stem borers in the order Lepidoptera.

25.f. Euplemid wasp; *Anastatus* sp.; Euplemidae: UC

A parasitoid of several pestiferous bugs in the family Coeridae (Order Hemiptera; plate16.d to 16.g). Used as a biocontrolling agent of bugs in horticulture farms.

25.g. Beneficial Fig wasp; _____; Agaonidae: C

Live inside Fig trees. Rarely seen outside the flower. Help in pollination of Fig trees.

25.h. Beneficial Fig wasp larva; Agaonidae: C

Grubs of these wasps live inside the fig. Lifecycle completed within a flower.

25.i. Non-beneficial Fig Wasp; *Torymus* sp.; Torymidae: C

Parasitoid of beneficial fig wasps (25.h); commonly seen on the surface of figs. Use the long ovipositor to deposit an egg on the grub/pupa of the beneficial fig wasp.

25.j. Pteromalid wasp; _____; Pteromalidae: UC

Small wasps; parasitoids of gall-forming insects (order Diptera).

25.k. Aphid wasp; _____; Aphelinidae: C

Extremely small wasps; parasitoids of aphids; seen close to aphid infestations.

25.l. Chalcid wasp; _____; Superfamily Chalcidiodea: C

An unidentified Chalcid wasp emerging from a pupa of *D. conoideum* (24.g).

25.m. Ensign wasp; _____; Evaniidae: UC

Occasionally seen inside human settlements; parasitoid of cockroaches.

25.n. Cuckoo wasp; _____; Chrysididae: C

Common during summer and monsoon; parasitoid of *D. conoideum*.

25.o. Scolid wasp; *Scolia* cf *affinis*; Scoliidae: C

Flower-visitor; pollinator. Parasitoids of scarab beetle larvae (Plate 10.h-10.k, 11.o)

Plate 25

Plate 26

26.a. *Apis dorsata*; Apidae: C

Large honeybee; most commonly seen are its honeycombs. Visits a number of flowers, including Mahua. Common near water sources during summer.

26.b. *Apis cerana*; Apidae: C

Smaller than *A. dorsata*. Common in forests and gardens.

26.c. *Apis florea;* Apidae: UC

Smallest of the three honeybees. Occasionally seen during monsoon.

26.d. Stingless bee; *Lisotrigona* sp.; Apidae: UC

Very small bee. Nest in tree or rock cavities. Honey is collected by tribal people.

26.e. Carpenter bee; *Xylocopa* sp.; Apidae: C

Large bees; visit several flowers including *Calotropis gigantea* and *Ipomea carnea*. Make large holes in dead trees for nest.

26.f. Blue banded bee; *Anthophora* sp.; Apidae: C

Flower visitor; more common in monsoon. Observed feeding on *Lantana camara*.

26.g. Mining bee; _____; Andrenidae: C

Small bee; flower visitor. Makes nest underground.

26.h. Sweat bee; _____; Halticidae: C

Brilliant metallic green bees, common near waterbodies such as wells. Often sits on hands to sip on sweat.

26.i. Leaf-cutter bee; _____; Megachilidae: C

Small bees resembling honeybee. Cuts leaves in arcs, especially of Tendu to build a nest inside small hollows in trees.

26.j. Mud dauber wasp; *Sceliphron* sp.; Sphecidae: C

Builds a typical irregular nest of mud containing multiple (>15) individual, elongated cells. Captures Orb weavers (*Neoscona* sp.) spiders for grubs.

26.k. Cricket wasp; *Sphex* sp.; Sphecidae: C

Nests underground and stacks cells with crickets (order Orthoptera) for the grub.

26.l. *Chalybion* sp.; Sphecidae: C

Commonly seen near human settlements. Captures Daddy Long Legs (Crossopriza sp.) spiders as food for grubs.

26.m. Spider wasp; *Pepsis* sp.?; Pompillidae: C

Large wasp; n. Captures Giant Wood Spider (*Nephila* sp.) for grubs.

26.n. Spider wasp; *Aporinellus* sp.?; Pompillidae: C

Small wasp; captures Huntsman spider (*Olios* sp.) for grubs.

26.o. Spider wasp; *Tachypompilus* sp.?; Pompillidae: C

Small wasp; occasionally seen scampering on the forest floor looking for spiders.

Plate 26

8. Orthoptera

Ortho = straight; *ptera* = wings

Orthoptera is the order of insects encompassing grasshoppers, crickets, katydids, and groundhoppers. This order is distributed across the globe and is especially common in agricultural fields. Swarms of some grasshoppers can cause heavy damage to crops, and such swarming species are called locusts. They are also the most vocal of insects, using wings and legs to create a peculiar sound which is well known amongst crickets. Adults vary in shape and size considerably. The smallest species of orthopterans live commensally in ant colonies, whereas the largest are voracious herbivores. The head is usually round or oval in shape, containing large eyes and a pair of many-segmented filiform antennae which are short in grasshoppers and longer in crickets and katydids. The thorax is rectangular and slightly rounded on the top, and the abdomen is long and cylindrical covered by two pairs of wings which rest parallel to the abdomen. Flight is generally weak in Orthoptera except in some swarming species, and use it only to cover short distances unlike most other insects. Their key characters are the long hindlegs modified for jumping or sprinting.

The lifecycle is paurometabolous (incomplete metamorphosis). Adults are vocal to attract mate. Once mated, a female lays eggs in the ground or in dense vegetative matter. The young ones (called nymphs) closely resemble adults except for the absence of wings and short bodies. Nymphs feed on vegetative matter and moult as they grow in size. After several moults, the nymphs develop wings to transform into adults. The nymphal and adult food source is the same; grasshoppers and katydids mainly feed on live vegetative matter, crickets on a mix of organic matter in leaf litter, and mole crickets mainly feed underground.

The most common three members of Orthoptera, viz. grasshoppers, crickets, and katydids can be told apart morphologically by observing the following characters: grasshoppers have an elongated body, short and thick antennae, and long, robust hind legs, and generally live in green undergrowth dominated by grasses. In katydids, the abdomen is rounded, antennae are thin and long (more than the length of the body), hind legs are long but not as robustly built as grasshoppers, and they usually live in green undergrowth or in the lower canopy. Crickets have stocky bodies with antennae as long as the length of their body, short but thick hind legs, and generally live in litter, crevasses, and under rocks.

Extensive studies have been made worldwide on this group of insects, largely because of their role in causing damage to standing crops. In 1961, Gage and Mukerji (1978) recorded the total loss in wheat production in Canada due to grasshoppers to be $40 million. The extent of crop damage can only be speculated to have shot up since. Most species however cause little to no damage to human food resources, but in fact serve a very important purpose in the undergrowth. Several species are omnivorous in nature, feeding on a range of organic matter on the forest floor, while some are important detritivores – feeding on decaying organic matter. The primary niche of such orthopterans is the undergrowth, which receives all the nutrient load of the upper canopy. Crickets in particular help reduce this matter into small pieces, providing an entry to fungus and other detritivores to take over. Owing to their sheer abundance, these insects form a part of the diet of many insectivores, and are probably next to winged termites and ants in terms of food preference of insectivores.

About 18000 species are known worldwide, of which more than 1750 recorded in India as per Alfred (1998), and several more have been discovered since. Chandra, Gupta and Shishodia (2007) have documented 139 species of Orthoptera from Madhya Pradesh and Chhattisgarh, of which they recorded 33 species from KTR. In the present study, 24 members have been documented belonging to 11 families. With the addition eight members, the Orthoptera diversity of KTR is 41 species.

This section provides images for the 24 members recorded in KTR under this study.

Plate 27

27.a. Toothpick grasshopper; *Acrida exaltata*; Acrididae: C

Slender grasshopper common in grasslands. Makes a peculiar *trr-trr-trr* sound while taking flight.

27.b. *Phlaeoba infumata*; Acrididae: C

Commonly seen in grasses.

27.c. *Trilophidia annulata*; Acrididae: C

Commonly seen in grasses. Has a babit of waving hindlimbs which is used as a signal to others of the species around.

27.d. *Aiolopus thalassinus tumulus*; Acrididae: C

Commonly seen in grasses.

27.e. *Spathosternum parasiniferum*; Acrididae: C

Commonly seen in grasses.

27.f. *Eyprocnemis alacris*; Acrididae: C

Commonly seen in grasses.

27.g. *Cyrtacanthacris tatrica*; Acrididae: C

Large grasshopper, commonly seen in areas with scanty groundcover.

27.h. *Gastrimargus africanus*; Acrididae: C

Commonly seen in grasses. Occasionally visits near lights at night.

27.i *Stenocatantops splendens*; Acrididae: C

Commonly seen in grasses, stays close to trees.

27.j. *Tetratodes monticollis* (Green morph); Acrididae: C

Common during monsoon. Feeds on leaves of trees.

27.k. *T. monticollis* (Yellow morph); Acrididae: C

Common during post-monsoon months.

27.l. *T. montocillis* (Brown morph); Acrididae: C

Common during drier months.

27.m. Green katydid; *Ducetia japonica*; Tettigoniidae: C

Common in forested areas, remains mostly on leaves in lower canopy; often visits lights at night.

27.n. Katydid; *Sathrophyllia* sp.; Tettigoniidae: C

Common in forested areas, rests on tree bark for camouflage.

27.o. *Schizodactylus monstrosus* (Moulting); Schizodactylidae: C

Large, ground-dwelling cricket; makes loud noise from burrows during monsoon.

Plate 27

Plate 28

28.a. *Atractomorpha* sp.; Pyrogomorphidae: C

Small grasshopper, common in grasslands and lawns.

28.b. *Chrotogonus* sp. (Adult); Pyrogomorphidae: C

Inconspicuous. Mostly found on barren grounds with a rocky surface and scant undergrowth.

28.c. *Chrotogonus* sp. (Nymph); Pyrogomorphidae: C

28.d. Ground hopper; _____; Tetrigidae: C

Small (<1inch) in size, commonly seen on ground, often get attracted to lights at night.

28.e. Ground hopper (Nymph); Tetrigidae: C

28.f. Tropical house cricket; *Gryllodes sigillatus*; Gryllidae: C

Common in human settlements than in forested areas.

28.g. *Loxoblemmus* sp.; Gryllidae: C

Common in forested areas as well as human settlements.

28.h. Bell cricket; *Homoeogryllus (=Meloimorpha) indicus*; Phalangopsidae: UC

Mostly seen only during monsoon. Discovered by Agarwal and KM Sinha (1988) in Madhya Pradesh.

28.i. Tree cricket; *Oecanthus indicus*; Oecanthidae: C

Common in shrubby areas.

28.j. Sword-tailed cricket; *Trigonidium* sp.; Trigonidiidae: C

Common in grasslands, especially near a water source. Often visit lights at night.

28.k. *Dianemobius* cf *Pteronemobius fascipes*; Trigonidiidae: C

Small cricket. Common near human settlements.

28.l. Mole cricket; *Gryllotalpa africana*; Gryllotopidae: C

Burrowing in habit. Often visits lights at night during monsoon. Feeds on roots and other organic matter in the ground.

28.m. Pygmy mole cricket; *Tridactylus* sp.; Tridactylidae: C

Small cricket, often seen near lights at night, more common during monsoon on wet bare ground than dry seasons.

Plate 28

9. Odonata

Odon = tooth; *ata* = having

Dragonflies and damselflies are one of the most ancient insects comprising the order Odonata. Dragonflies belong to suborder Anisoptera, and damselflies to Zygoptera. The distinction between the two suborders can be told morphologically by observing the following characters: in dragonflies, the head is round with both the eyes joining in the middle, whereas in damselflies it is cylindrical, and the eyes are placed apart at the opposite ends. The thorax in both groups is roughly squarish, but longer in damselflies. Dragonflies have a thick, long abdomen whereas damselflies have a long, slender one. Dragonflies almost always rest their wings open (i.e. parallel to the plain of the body), or often below the level of the body while at rest. Damselflies keep their wings folded over the abdomen, with the exception of Emerald Spreadwings (*Lestes* sp.) which keep their wings open at rest.

Odonates are hemimetabolous; they undergo incomplete metamorphosis. Adults engage in an interesting courtship dance, with males often presenting females with an insect (called nuptial gifts) to snack on. Mating almost always takes place near a water body, and the females lay eggs on twigs and grasses submerged underwater by inserting their long abdomen inside. Nymphs (called naiads) are completely aquatic, and look distinctly different than the adults. They are predatory in nature and hunt fishes and aquatic invertebrates. Nymphs are commonly seen in unpolluted water bodies, such ponds, lakes, streams and rivers. They emerge from the water and onto nearby vegetation or rocks between evening and morning hours to transform into adults. Teneral adults emerge from the nymphs without the formation of a pupa, and take to flight after their wings expand and dry. Adult dragonflies and damselflies are also voracious feeders of invertebrates, mainly insects and spiders.

The capacity and applicability of odonates in controlling mosquito populations is widely studied, mostly because nymphs feed on mosquito larva underwater and adults feed on adult mosquitoes on land. This dual-control of malaria-causing pests is most effective near areas with water bodies which can sustain the odonate population. Several studies have shown promise in using odonate naiads in controlling mosquito larva in wetlands, and high predation has been recorded amongst adult odonates (especially damselflies) in feeding on adult

mosquitoes. Odonates are also considered ecologically important as indicators of the ecosystem health. High diversity and/or high endemism correlates to unpolluted, and often pristine ecosystems. On the other hand, increase in the density of some species is often linked with disturbed, or polluted, ecosystems, since only a handful few of these are capable of withstanding polluted environments (especially water), giving them an upper edge on surviving in such conditions.

Dragonflies are also known for their migratory nature, and one in particular, the Wandering Glider (also called Globe Trotter), *Pantala flavescens*, is known to undertake the longest migration of any insect. Hobson et al (2012) compared stable isotopes analyses to prove its migration from Northern India to Maldives and further on to East Africa, covering over 18000 km in about four generations. Clusters of Wandering Gliders are commonly seen across KTR during pre- and post-monsoon months, although the authors speculate that the migratory clusters do not originate in the region, KTR falls under its proposed migratory path from northern India.

Over 5740 species of odonates have been recognized globally, of which 470 are found in India (Subramanian 2009). In the central Indian context, 45 species are said to occur *commonly* (Andrew, Subramaniam, and Tiple 2008); comprising of 32 species of dragonflies and 13 species of damselflies. Odonata diversity of KTR is well studied. Tiple, Kulkarni and Joshi (2010) recorded 36 species of odonates in Kanha National Park, and were the first to study the odonate diversity of the park. Subsequent studies by Das et al (2013) and Sahoo, Das and Parida (2013), recorded 44 and 48 species respectively. In the present study, 40 species of odonates were recorded (26 species of dragonflies, and 14 species of damselflies). Four species (*Zyxomma petiolatum*, *Gynacantha bayadera*, *Agriocnemis splendiddissima*, and *Vestalis gracilis*) are new records for KTR.

Considering all the recorded sightings, KTR's odonate diversity is 52 species. This section provides photographs and information on 40 species recorded in the present study.

Plate 29

29.a. Blue darner; *Anax immaculifrons*; Aeshnidae: C

Commonly seen during monsoon near still waterbodies such as ponds, wells, and lakes. One of the largest dragonflies of KTR.

29.b. Blue tailed green darner; *Anax guttatua*; Aeshnidae: C

Seen during monsoon months near slow-flowing streams and ponds. Size similar to Blue darner.

29.c. Parakeet darner; *Gynacantha bayadera*; Aeshnidae: C

Seen mostly in dense forested areas, away from waterbodies. A crepuscular species, mostly found roosting in dense thickets.

29.d. Common hooktail; *Paragomphus lineatus*; Gomphidae: C

Seen in open areas, perches on the ground.

29.e. Common clubtail; *Ictinogomphus rapax*; Gomphidae: C

Seen perching in less dense thickets. Also observed far from any waterbody.

29.f. Brown dusk hawk; *Zyxomma petiolatum*; Libellulidae: C

Crepescular species, mostly seen flying over still waterbodies during evening.

29.g. Yellow tailed ashy skimmer; *Potamarcha congener*; Libellulidae: C

Seen near a variety of waterbodies. Perches on overhanging branches.

29.h. Long legged marsh skimmer; *Trithemis pallidinervis*; Libellulidae: C

Seen during monsoons in grasslands close to still waterbodies.

29.i. Blue marsh hawk; *Orthetrum glaucaum*; Libellulidae: C

Seen near undisturbed flowing waterbodies such as streams in dense forests.

29.j. Green marsh hawk; *Orthetrum sabina*; Libellulidae: C

Seen in all habitats of KTR. Mostly seen perching on small herbs.

29.k. Granite ghost; *Bradionpyga geminata*; Libellulidae: C

Seen near streams, mostly perching on flat rocks. Also common near human habitations near a source of water where they perch of walls. Roost in large numbers in trees or near houses.

29.l. Ground skimmer; *Diplacodes trivialis*; Libellulidae: C

Seen in all habitats of KTR. Small dragonfly perching on ground; flies very close to ground. Females are green in colour.

29.m. Trumpettail; *Acisoma panorpoides*; Libellulidae: UC

Seen in grassland egdes. Habit similar to that of Ground skimmer.

29.n. Black stream glider; *Trithemis festiva*; Libellulidae: C

Seen near steady-flowing streams. Indicator of good health of stream ecosystems.

29.o. Asiatic bloodtail; *Lathrecista asiatica*; Libellulidae: C

Seen in dense forests, females often seen in groups. Males remain solitary.

Plate 29

Plate 30

30.a. Ruddy marsh skimmer; *Crocothemis servilia*; Libellulidae: C

Seen in all habitats, also common in gardens. Females are orange in colour.

30.b. Coral tailed cloudwing; *Tholymis tillagra*; Libellulidae: C

Seen near forest openings, especially near dense deciduous forests.

30.c. Wandering Glider; *Pantala flavescens*; Libellulidae: C

Most common dragonfly of KTR, seen in most habitats. Large clusters are seen during pre and post-monsoon months. Roost in thickets at night.

30.d. Crimson marsh glider Male; *Trithemis aurora*; Libellulidae: C

Seen near streams and ponds.

30.e. Crimson marsh glider Female; *Trithemis aurora*; Libellulidae: C

Seen near streams and ponds, less commonly seen than males because of dull colouration.

30.f. Crimson tailed marsh hawk; *Orthetrum pruinosum*; Libellulidae: C

Seen near ponds, often perch high in the canopy.

30.g. Fulvous forest skimmer; *Neurothemis fulvia*; Libellulidae: C

Seen near ponds in dense forests. Especially common during monsoon.

30.h. Pied paddy skimmer; *Neurothemis tullia*; Libellulidae: C

Seen near edges of paddy fields, especially those on forest edges.

30.i. Common picturewing; *Rhyothemis variegata*; Libellulidae: UC

Seen in forest openings, often perch high on a tree.

30.j. Ditch jewel; *Brachythemis contaminata*; Libellulidae: C

Seen near slow flowing streams and ponds. Large populations of this species is said to indicate some degree of pollution of the waterbody.

30.k. Ruddy meadow skimmer; *Neurothemis intermedia*; Libellulidae: C

Seen in forested areas of KTR, often in very large congregations during summers.

30.l. Red marsh trotter; *Tramea basilaris*; Libellulidae: UC

Seen in forest clearings, especially near grasslands close to a waterbody.

Plate 30

Plate 31

31.a. Pigmy dartlet; *Agriocnemis pygmaea*; Ceonagrionidae: C
Seen in grasses and herbs close to still waterbodies.

31.b. Senegal golden dartlet; *Ischnura senegalensis*; Coenagrionidae: C
Seen near ponds and slow flowing streams, often in a mixed community of Pigmy dartlet and Golden dartlet.

31.c. Golden dartlet; *Ischnura aurora*; Coenagrionidae: C
Similar in habit and share the same habitat as Senegal golden dartlet. However they are also seen quite far from any waterbody.

31.d. Coromandel marsh dart; *Ceriagrion coromandelianum*; Coenagrionidae: C
Seen near almost all types of waterbodies. Large clusters of this damselfly (and absence of other species) may indicate poor water quality.

31.e. Saffron faced marsh dart; *Pseudagrion rubriceps*; Coenagrionidae: C
Seen near forested ponds and slow flowing streams.

31.f. Blue grass dartlet; *Pseudagrion microcephalum*; Coenagrionidae: C
Seen near ponds often in association with Saffron faced marsh dart.

31.g. Splendid dartlet Male; *Pseudagrion splendidissima*; Coenagrionidae: C
Seen near forested ponds.

31.h. Splendid dartlet Immature; *Pseudagrion splendidissima*; Coenagrionidae: C
Immature state of this damselfly closely resembles the female, which is quite distinct from the male (31.g)

31.i. Rusty dart; *Aciagrion pallidum*; Coenagrionidae: UC
Seen in dense forested areas, often away from any waterbody.

31.j. Yellow bush dart; *Copera marginipes*; Platycnemididae: C
Seen near all waterbodies, flowing as well as still. Large clusters of this damselfly may indicate poor water quality.

31.k. Brown spreadwing; *Lestes umbrinus*; Lestidae: C
Seen in forested and grassy areas, far from waterbodies. Roost in clusters.

31.l. Black tipped forest glory; *Vestalis apicalis*; Calopterygidae: UC
Seen in densely forested streams.

31.m. Blackwinged bambootail; *Disparoneura quadrimaculata*; Protoneuridae: C
Seen in all habitats of KTR, mostly close to ponds and streams.

31.n. Black bambootail; *Prodasineura verticalis*; Protoneuridae: UC
Seen mostly during monsoon near slow flowing forest streams.

31.o. Clear winged forest glory; *Vestalis gracilis*; Calopterygidae: C
Seen in densely forested streams, more common than 31.l.

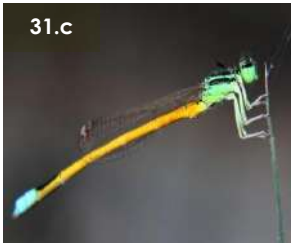
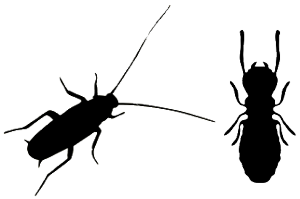


Plate 31

10. Blattodea



Blatta = light-avoiding insects; *odea* = variety

Blattodea literally means insects (specifically roaches) which avoid lights, and encompasses cockroaches and termites. The latter were first placed in their own order Isoptera, which has now been incorporated within Blattodea as an infraorder (Kumar et al, 2013), based on several morphological and genetic similarities with cockroaches.

Cockroaches and termites are distinct in appearance as well as habit. While most cockroach species are winged, only queen and drone termites possess wings – and are the most common flying insects seen near lights during pre-monsoon showers. Cockroaches are solitary, and although very common in human settlements where they feed on leftover food, they are abundantly found on the forest floor where they do the important ecosystem service of degradation of organic detritus such as decomposing leaves and animal matter. Termites, on the other hand, are social insects, and are important in forest ecosystem although they are considered pests in human settlements. In forests, termites are crucial in feeding and nesting in deadwood, enabling entry of fungus and other organisms inside deadwood for its further breakdown. Termites also form an important part of the diet of the Sloth Bear (*Melursus ursinus*).

They are paurometabolous. Female cockroaches lay eggs in the form of an ootheca, an eggsac containing a number of eggs from which little nymphs roughly resembling the adults hatch. The diet of nymphs and adults remains the same, and they grow by periodically moulting. Teneral (= recently moulted insects), appear white before they resume their new, original colours. In termites, only queens lay eggs – and can lay as many as a hundred to thousand in a day. Strong division of labour, as seen is ants, is observed in termites, with the members broadly classified as workers, soldiers, kings, and queens. Workers further divide their labour in foraging and harvesting, food storage, feeding other members of the colony, and building and maintenance of the termite mound.

About 4000 species of cockroaches are known worldwide, of which about 156 species are known from India (Gaikwad, Koli and Bhawane 2014). The authors also enlist studies pertaining to this group, which is divided geographically, with 14 species recorded from Andhra Pradesh, 26 from Meghalaya, 17 from Sikkim, 10 from Tripura, 16 from West Bengal, 47 from Tamil Nadu, and 12 from Maharashtra.

Cockroach diversity from Madhya Pradesh is largely unknown. In the present study, 7 individuals have been identified up till genus level belonging to three families. Most of these, except *Periplenata americana* which is mostly found in human settlements, are found in forested areas with a dense leaf litter. Their ecological importance in this niche is rather important and probably only next to that of crickets which share the same habitat.

In terms of termites, about 3106 species are known worldwide (Kumar *et al* 2013), of which 337 species of termites are recorded from the Indian subcontinent (Rao, Samantha, and Sammaiah 2012) including 95 species from southern India. Four species have been recorded by Kumar and Thakur (2010) with known distribution in Madhya Pradesh. Four species, *Euhamitermes kanhaensis*, *Eurytermes boveni*, *Pericapriermes tetraphilus*, and *Odontotermes bhagwatti* were first described in KTR by Zoological Survey of India in 1995 (KTR management plan 2001-2011). Chhotani (1977) first studied the diversity of termites of KTR, who discovered the aforementioned species new to science. About 16 species of termites are known from KTR (Chhotani 1977; Shrivastava, Masih, Homkar n.a.),

The most common termite of KTR is *Odontotermes* (cf *obesus*) which build small to large termite mounds commonly seen inside the park. These mounds can be underground, with only small protrusions visible above ground (Roonwal, 1977), or as high as seven feet. Since identification of termites from photographs is not possible, they have been broadly classified in the following types for the ease of understanding their ecological roles:

a. Mound builders: These termites build large, tall mud structures common in open areas. They are more common in areas with red soils. Although the mounds are tall, a significant portion of the nest is also underground.
b. Underground dwellers: These termites largely occupy areas underground and aboveground, with signs of decaying wood commonly observed around. More common in dense forests, with nests commonly found under rocks.
c. Wood dwellers: Some species also occupy live weak and dead trees by tunneling under the bark and creating passages and chambers. Some species build trails on the outside of barks and cover it in coarse mud and wood particles, such trails generally lead to a tunnel inside the tree.

Plate 32

32.a. Bush cockroach; *Blatella* sp.; Blatellidae: C

Seen in forest undergrowth, often get attracted to lights at night.

32.b. Bush cockroach; *Blatella* sp.; Blatellidae: C

Seen in forest undergrowth, often get attracted to lights at night.

32.c. Bush Cockroach; *Blata* sp.; Blatellidae: C

Mostly observed near lights at night. Probably shares same habit as 32.a.

32.d. Oriental cockroach; *Blatta orientalis*; Blattidae: C

Large species mostly seen in forest undergrowth with dense leaf litter.

32.e. American cockroach; *Periplaneta americana*; Blattidae: C

More common in human settlements than in natural vegetation.

32.f. *Pycnoscelus* sp.; Blaberidae: C

Mostly observed near lights at night in monsoon.

32.g. *Periphaerus* sp.; Blaberidae: C

Seen in forest undergrowth with moderate to scant leaf litter.

32.h. Bush Cockroach; *Blatella* sp. scavenging on a dead beetle

Cockroaches are omnivores, feeding on a variety of dead and decaying organic matter. In the leaf litter, they feed on dead plant matter as well.

32.i. Cockroach nymphs emerging from the ootheca

Cockroaches lay a single ootheca containing several eggs. Nymphs resemble adult cockroaches but lack wings and matured reproductive organs.

32.j. Termite mound; *Odontotermes* cf *obesus* mound;; Termitidae: C

Most commonly seen in grasslands and forest edges.

32.k. Underground dwelling termite; _____: C

These termites are rather pale in colour. Also seen is a developing alate termite.

32.l. Wood dwelling termite; _____: C

These termites carve tunnels in deadwood, often damaging manmade structures.

32.m. Mound building termite ; *Odontotermes* sp.; Termitidae: C

A typical worker termite.

32.n. Alate termite

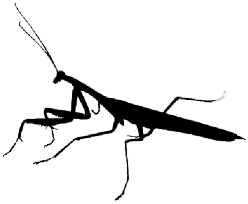
During the first showers, millions of alate termites rise from termite colonies. Most commonly seen near lights at night. Once mated, they shed their wings and explore the ground for a suitable nesting site. Alates form a major part of the diet of carnivorous insects, spiders, as well as birds.

32.o. Wood decay by termites

Termites play a crucial role in the breakdown of fallen logs, enabling other decomposers to enter the wood and releasing nutrients into the ground.

Plate 32

11. Mantodea



Mantis = prophet; *odea* = variety

Mantids, or Mantis, are a group of insects in the order Mantodea known for their forelegs adapted to catch prey – and act like "hands" – called raptorial legs. Their name Praying Mantis comes from the way they fold their forelegs, which appears as though they are praying. Mantids typically have a triangular head with two large compound eyes – their flexible prothorax allows them to turn their head around which is not possible for most insect orders.

Mantids have one of the best visions in the invertebrate world, upon which they primarily rely while hunting. They have a slender thorax, and a long abdomen on which two pairs of wings rest. Wings are present in most species; however in some they are vestigial. In several species, these wings are vividly coloured and contain false eyes which they expose when threatened, or match the green or brown colour of the surrounding. Camouflage is commonly observed in most mantids. Some mimic green or brown leaves, slender stems, and some adorn colours of flowers as they wait in ambush for prey to arrive.

Raptorial legs are often dentate and serrated, which they use to capture prey. They are obligate carnivores, and prey on a number of invertebrates. Some large species are also known to feed on lizards. Albeit their large, and often menacing, look, they are harmless to humans.

Their closest living relatives are cockroaches, and are considered to have evolved from a common ancestor. Mantids are hemimetabolic, females deposit eggs in a foamy ootheca which hardens when exposed to air. An ootheca can contain several hundred eggs depending upon the species. Nymphs resemble adults except for lack of wings and colouration. Nymphs of some species mimic ants, whereas some are excellent at mimicking dry leaves and stems. They feed on small invertebrates as they grow old. Wings are developed in the last instar, when they attain their adult features.

Mantid nymphs are especially common during post-monsoon and summer seasons, and adults are common during late-summer and early-monsoon. They inhabit a variety of niches – from the dense undergrowth to barren secondary forests, to tree canopies in the dense Sal forests, feeding on grasshoppers, beetles, butterflies and moths, spiders, and other invertebrates.

They chiefly play two roles ecologically, by feeding on pestiferous insects, and their diversity indicates a healthy ecosystem. Being palatable, they also serve as a food-source for insectivorous animals.

Over 2400 species of mantids are known worldwide (Otte *et al* 2015), of which 184 species in 11 families are found in India (Ghate *et al* n.a.). The authors also mention 25 species from Madhya Pradesh.

Mantid diversity of KTR is largely unknown. In the present study, 10 members have been recorded, of which 1 remains unidentified. This section provides images of these species, along with the image of a typical mantis nymph and an ootheca.

Plate 33

33.a. Praying mantis; *Creobroter* sp.; Hymenopodidae: C

Seen near lights during monsoon. Often inhabit flowering plants and wait in ambush for insects that visit flowers.

33.b. *Ephestiasula* sp.; Hymenopodidae: C

Similar in habit as *Creobroter* sp. Often seen attracted to lights at night.

33.c. Bark mantis; *Humbertiella* sp.; Hymenopodidae: C

Commonly seen on tree trunks where they blend into the surrounding.

33.d. Bark mantis; *Amorphoscelis* sp.; Amorphoscelidae: UC

Share the same habit as *Humbertiella* sp., however they are mostly found in dense Sal forests.

33.e. Stick mantis; *Schizocephala bicornis*; Mantidae: C

Longest insect of KTR. Mimic stems and grass blades. Seen near forest edges.

33.f. *Statilia maculata*; Mantidae: C

Mimics stems, often seen near lights at night during monsoon months.

33.g. *Tropidomantis* sp.; Iridopterygidae: UC

Remains close to ground, often in herbs and on forest floor with moderate to dense leaf litter.

33.h. Praying mantis; *Hierodula* sp.; Mantidae: C

Seen in a variety of forest habitats of KTR. Often get attracted to lights at night.

33.i. Ground mantis; _____; cf Thespidae/Mantidae: C

Mostly seen on the ground in grasslands and forest edges.

33.j. *Phyllothelys* sp; Mantidae: UC

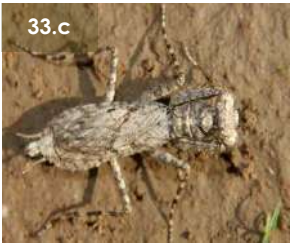
Often seen near lights at night during monsoon. Prefers vegetation closer to ground.

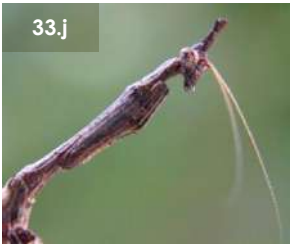
33.k. A typical nymph of a praying mantis

A mantis nymph mimics dead leaves and stems, as well as ants.

33.l. A typical ootheca of a praying mantis

Mantis lay ootheca on a blade of grass or stems. It is a foamy structure containing several eggs that hardens when exposed to air.





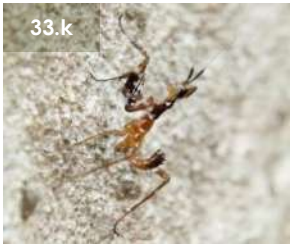


Plate 33

12. Neuroptera

Neuro = veined; *ptera* = wings

Neuroptera encompasses insects such as lacewing, antlion, owlfly, and mantidfly. They are considered to be one of the oldest insects, with their first ancestors flying on the planet over 250 million years ago. They can be distinguished by the presence of translucent, veined wings which appears like a net, with both the pairs of roughly equal size. Their head is either triangular (especially in antlions and mantidflies) or globular like that of dragonflies (in owlflies). Thorax is generally squarish except in mantidflies which have a long prothorax in the form of a "neck". Abdomen is generally long and slender, except in mantidflies and some owlflies which have a roughly boat-shaped abdomen. Neuropterans are predatory insects, where both the larva and the adult feed on other small invertebrates, especially insects, with an exception of mantidflies which are parasitic on insects such as bees, wasps, and scarab beetles. Interestingly, they seek out spiders or spider egg sacs and feed on it until they develop into a pupa.

Insects of this order undergo complete metamorphosis; with the major families discussed here following different paths of lifecycle. Antlions lay eggs in sandy areas, where the larva build cone-shaped structures of fine sand called sand traps. The larva sits at the very bottom of the trap with its large mandibles wide open. These traps, when treaded upon by ants, cascade downwards, tumbling the ant down to the bottom. The larvae also throw streams of sand towards the potential prey if it manages to scamper up. After reaching full size, they pupate and emerge as winged adults, which feed on other small insects. Lacewings lay eggs on plant stems and leaves. The eggs are typically laid at the end of a long (>1cm) stalk to avoid being eaten by other insects such as ants. The larvae are mobile and cover themselves with debris and often with the remnants of their prey. They pupate in soil, and adults mostly emerge near the beginning of monsoon. The adults and the larvae are considered effective biological pest controlling agents in farms where they feed on a number of pest species. Mantidflies are parasitic as larvae (discussed above), and adults are predatory, using their mantis-like raptorial legs to capture prey. Owlflies lay eggs on the undersurface of leaves, which appear as brownish oval clusters. The larvae appear similar to an antlion's except for the presence of spiny projections alongside the abdomen. They are predatory as well, and feed on a number of insects as they grow in size and pupate in the soil. Adults are commonly observed

during monsoon months near lights. Owlflies are crepuscular species, and prefer to stay still on branches by holding their abdomen up to appear like a stick during most of the day.

An estimated 6000 species have been recorded worldwide, with about 335 species belonging to 13 families known from India (Alfred 1998). 33 species are known from Madhya Pradesh and Chhattisgarh (Chandra *et al* 2014), most known for their predatory nature and in potential use in biocontrol of agricultural pests.

Neuropteran diversity of KTR is unknown, although its pristine ecosystems are likely to harbour a rich variety of them. Since identification of this group is based on microscopic observations, in the present study, only individual members identified on their morphology are considered. Four families of Neuroptera have been identified under the present study represented by seven individuals. This section provides images and ecology of Neuroptera of KTR.

Plate 34

34.a. Green lacewing; *Chrysoperla* sp.; Chrysopidae: C

Seen near lights at night, especially common during monsoon. Found in herbs and shrubs in natural habitat where they feed on small insects such as aphids.

34.b. Green lacewing eggs; *Chrysoperla* sp.; Chrysopidae

Stalked eggs are commonly laid on lower herbs and shrubs.

34.c. Lacewing larva: UC

Larva cover themselves with debris, often of dead prey as camouflage.

34.d. Antlion; *Palpares* sp.; Myrmelontidae: UC

Large antlion, often seen during post-monsoon months.

34.e. Antlion; _____; Myrmelontidae: C

More common than *Palpares* sp., often found in grassy and dense thicket areas.

34.f. Antlion larva

Live in sandy areas, primarily predate on ants.

34.g. Antlion larva sand trap

Antlion larva make sand traps which appear like a funnel lined by thin sand, and rest at the bottom. Any passing insect when fallen tumbles down into its jaws.

34.h. Owlfly; _____; Ascalaphidae: C

Often seen near lights at night, or resting on herbs closer to the ground. Slow flier, can be told apart from dragonflies by the presence of long, clubbed antennae.

34.i. Owlfly; _____; Ascalaphidae: UC

Often seen near lights at night, or resting on herbs closer to the ground.

34.j. Owlfly larva

Told apart from Antlion larva by presence of finger-like projections from abdomen, cover themselves in debris such as sand without building the typical sand trap.

34.k. Owlfly eggs

Eggs are laid on the under surface of leaves.

34.l. Mantidfly; _____; Mantispidae: UC

Occasionally visit lights at night; predatory in nature.

34.m. Mantidfly; cf *Euclimacia* sp.; Mantispidae: R

Occasionally visit lights at night; predatory in nature. Probably mimics Potter Wasp (24.i).


34.a


34.b


34.c


34.d


34.e


34.f


34.g


34.j


34.h


34.i


34.k


34.l


34.m

Plate 34

13. Other insect Orders

The diversity of insects of KTR extends to some rather uncommon orders as well. Eleven insect orders have been combined into this chapter owing to their low diversity and low level of understanding of their taxonomy and ecology. Although they share a minute portion of KTR's diversity, their existence in the landscape, and indeed the entre globe (some are as ancient as the dinosaurs), is justified by the ecological role they play. Most of these orders are herbivores, detritivores, parasitic, and scavengers. Their presence, owing to their low diversity, is therefore a direct indicator of ecosystem health. Some also show extensive parental care of their young, a trait well known amongst higher organisms; some are web-builders, a trait shared by very few insects; and some cannot survive without the source of clean flowing water.

13.1. Dermaptera (*Derma* = skin; *ptera* = wings) (Earwig)

Their body structure is similar to that of beetles (esp. rove beetles) however they can be distinctly recognised by the presence of two pincer-like projections at the posterior end called cerci or forceps. They are most common in and around homes, especially in damp places, where they scavenge on organic matter. Some are also predatory, while some feed on pollen and possibly help in pollination. Albeit of their appearances and occurrence around homes, they are harmless to humans. They are hemimetabolous, and parental care is commonly observed in this group of insects. Of the 1800 species known worldwide, 320 to 350 are recorded from India (Alfred, 1998; MOEF, 2009). About four members have been recorded from KTR in the present study.

13.2. Embioptera (*Embiso* = lively; *ptera* = wings) (Webspinner)

They are small (<1cm), cylindrical and dark-coloured insects with enlarged forelimbs containing silk-producing glands which helps in building silken galleries underneath the barks of trees. Females are wingless and males winged. Males are more commonly seen than females, which seldom venture out of the retreats. Winged males are occasionally seen near lights at night, especially during monsoon. They feed on plant matter – mostly moss and lichen – and live in small colonies in silken galleries. They are hemimetabolous, with nymphs roughly resembling adults. About 360 species have been recorded worldwide (Engel and Grimaldi, 2006), and 31 to 33 are known from India (MOEF, 2009; Alfred, 1998). It is probably represented by only one species in KTR.

13.3. Plecoptera (*Plekein* = to braid; *ptera* = wings) (Stonefly)

Stoneflies are associated with clean flowing waters, and act as indicators of good health of an aquatic ecosystem. They are small, (<1cm) and dark-coloured, and closely resemble webspinners except for the lack of thickened forelimbs and presence of long cerci. They mostly lead an aquatic life as nymphs, feeding on algae underwater. Adults are winged and are occasionally found near flowing forest streams. Of the 3500 species discovered so far, about 113 species are known from India (MOEF, 2009; Alfred, 1998). Most species are known from Himalayan and "hilly regions" of southern India, however records of stoneflies from other regions, especially central India, are scarce and their distribution in Indian context largely unknown.

13.4. Ephemeroptera (*Ephemeros* = lasting a day; *ptera* = wings) (Mayfly)

Mayflies are small insects with an elongate body and long cerci. They have a habit of holding their forelimbs stretched in front of their head, and hold wings upright similar to damselflies. They mostly lead an aquatic life where the nymphs are detritivores (some species are predatory), however adults do not feed and lead a very short life. They are hemimetabolous. This order is unique in terms of its lifecycle. Nymphs, in the second-last phase of moulting, emerge as subimago which is winged, which then undergoes the last moulting to emerge as adults called imago. Over 3000 species are known worldwide, of which 106 species are found in India (MOEF, 2009). KTR is home to at least two species, both fairly commonly observed at lights especially during monsoon near flowing waters.

13.5. Trichoptera (*Trichos* = hair; *ptera* = wings) (Caddisfly)

Caddisflies are mostly observed near lights at night, or in thickets near wetlands. They are moth-like in appearance, containing long, filamentous antennae, but a rather small mouth with large eyes, and brown wings with scant cover of scales. Unlike in Lepidoptera, wing venation is visible in caddisflies. They are holometabolous, with females laying eggs in water, where the larvae lead an aquatic life. They larva are known for building cases of sand particles, and feed on aquatic detritus such as algae, some species are known to be predators. They pupate underwater, and emerge as adults especially during first monsoon rains. Presence of caddisflies, in combination with stoneflies and mayflies, is considered as an indicator of good ecosystem health. About 13574 species are known globally, of which over a 1000 recorded from India, with entomologists estimating 2000 more which remain undiscovered (Kaur, 2012). KTR's Trichoptera diversity is unknown, and only one representation has been made under this study.

13.6. Phasmida (*Phasma* = phantom; *ida* = pertaining to) (Stick insect)

Stick insects are elongate, slender, and stick-like in appearance, commonly found in trees and shrubs where they feed on leaves. They are docile and rarely fly. They are hemimetabolous, with the females laying eggs in the soil that appear like grains or small stones. Nymphs closely resemble adults, and feed on vegetable matter. They are more often seen during summer when they enter homes to seek shade, and during monsoon. Of the 3000 species known worldwide, about 150 are recorded in India (MOEF, 2009). They are rather uncommon to come across in forests owing to their camouflage, but their diversity in KTR is rather low as well, probably represented by only one or two species.

13.7. Thysanura (*Thysanos* = fringed; *ura* = tail) = Zygentoma (Silverfish)

Silverfish are rather common inhabitants of damp corners of our houses, especially in old bookshelves. They are wingless and have a tapering body like that of a fish, with silvery scales covering the entire body, with three long segments at the tip of their abdomen. They feed on organic matter, from starch to meat. Their natural habitat is moist leaf litter, however they are seen more commonly at homes than in the wild. They are hemimetabolous, with the young ones resembling the adults. About 1250 species have been documented worldwide, of which 23 species are known from India (Jairajpuri, 1991). This poorly studied order is represented by at least a species in KTR, but there are higher chances of discovering others.

13.8. Thysanoptera (*Thysanos* = fringed; *ptera* = wings) (Thrips)

Thrips are extremely small insects (<0.5cm) commonly seen inside flowers or on the forest floor, often black in colour, elongate, and seen in groups. Some species are extremely narrow and needle-like in appearance. They are hemimetabolous, with the females laying eggs on leaves, and the nymphs resembling adults. They feed mainly on plant matter (some are known to feed on animal matter as well), especially flowers, making them pests in some agricultural fields. They are commonly seen on wildflowers, and probably act as pollinators of some. Over 6000 species are known worldwide, several known for being pestiferous, of which 693 are recorded in India (Alfred 1998). KTR has at least a species, and probably several, of thrips found in all types of ecosystems. Their small size however makes them difficult to see on field.

13.9. Psocoptera (*Psocus* = gnawed; *ptera* = wings) (Barklice)

Barklice are very common near damp places in homes, especially if located near a forested area. They are very small (<0.5cm) with an oval abdomen upon which wings are held at rest, and resemble Hemiptera insects if observed closely. Their natural habitat is tree barks where they feed on moss and lichen. They are hemimetabolous, with the young ones closely resembling adults. They act as indicators of dampness at homes, and are commonly found in such areas during summer. Of the 2500 species known worldwide, 230 genera are known from India (Alfred, 1998). Psocoptera diversity of KTR is largely unknown, but they are a common insect of its ecosystems.

13.10. Phthiraptera (*Phtheir* = louse; *aptera* = wingless) (Louse)

Louse is an ectoparasite, feeding on the blood of warm-blooded animals. They are hemimetabolous and complete the lifecycle on their host. Adults are wingless and extremely small with a flattened body and an abdomen which is longer than the head and thorax combined. They are economically known for transmitting diseases from host to host. The most common species, *Pediculus humanus humanus*, is a parasite on humans. There are several species found in wild mammals and birds, with studies being undertaken on house crow, grey rock pigeon, common myna, red avadavat and Indian peafowl. An estimated 3000 species are recorded globally, of which 400 are known from India (MOEF, 2009). KTR hosts several species of louse, including those that reside on humans. Based on modern taxonomy, Psocoptera and Phthiraptera are clubbed into one order Psocodea.

13.11. Siphonaptera (*Siphon* = tube; *aptera* = wingless) (Flea)

Flea is also an ectoparasite. They are commonly found on mammals and birds, and are holometabolous. Adults are dark brown in colour, laterally compressed, wingless, and contain long hindlegs used in jumping long distances. Eggs are usually laid onto the host where the larva hatch and feed on organic detritus where the host usually rests. After pupation, adults solely feed on blood. They are of significant economic importance as large infestations on pets and livestock can be harmful, and they act as disease vectors from animals to humans. Their bites can cause itching which can last for months. Of the 2000 or so species recorded worldwide, 52 are known from India (Jairajpuri, 1991). KTR's flea diversity is unknown, but they are fairly common amongst domestic and wild animals.

Plate 35

35.a. Earwig; cf *Labidura* sp.; Labiduridae; Dermaptera: C

Most common near lights; prefers damp areas to live in, Scavenging in nature.

35.b. Earwig Nymph; _____; Diplatyidae; Dermaptera: C

Nocturnal, often seen near crevasses close to ground a few days before monsoon. Scavenging in nature.

35.c. Earwig; *Forcipula* sp.; Labiduridae; Dermaptera: R

Occasionally seen in dense thickets or near lights at night. Scavenging or detritivore in nature.

35.d. Webspinner Male; _____; Embioptera: C

Live on tree bark where they build silken galleries; males often get attracted to lights at night, especially during pre-monsoon showers. Females rarely seen.

35.e. Stonefly; _____; Plecoptera: UC

Adults observed on rocks near streams and rivers. Larvae are aquatic.

35.f. Mayfly; _____; Ephemeroptera: C

Adults commonly seen during pre-monsoon showers, occasionally during irregular summer showers; get attracted to lights at night. Larvae are aquatic.

35.g. Mayfly; _____; Ephemeroptera: C

Extremely small. Common than the previous; sharing same habit and habitat.

35.h. Caddisfly; _____; Trichoptera: C

Adults commonly observed near lights at night. Larvae are aquatic.

35.i. Stickinsect; _____; Phasmida: C

Common in all vegetation types; hard to see because of their stick-like appearance. Feed on foliage. Often take shelter at homes during summer.

35.j. Silverfish; _____; Thysanura: C

Common especially in dark, damp places which are unclean. Feeds on organic detritus. In nature, found in leaf litter where they take shelter under soil or rocks.

35.k. Thrips; _____; Thysanoptera: C

Seen on flowers, often in small or large numbers.

35.l. Barklice; _____; Psocoptera: C

Common in damp places in homes; prefer moist tree barks in nature, feed on moss and lichen. Indicator of dampness at homes.

35.m. Louse; _____; Phthiraptera: C

Seen mostly on humans, several species also found on birds.

35.n. Flea; _____; Siphonaptera: C

Seen mostly on pets, rodents, and other wild animals.

Plate 35

13.12. Non-insects

There are several non-insect arthropods (excluding crabs and shrimps, which are primarily aquatic) that share the same habit, habitat, and niches as insects. Most of these resemble insects but can be told apart by some simple morphological observations, such as presence of more than three pairs of legs. At least about nine non-insect arthropod orders exist alongside insects, commonly seen in all types of vegetation in KTR. The most common non-insect arthropod of KTR is Springtail (formerly considered an insect, now placed in a different class Entognatha), followed by millipedes and centipedes. Some of the common ones are provided here. About 10 specimens (identified upto genus/family/order level are discussed in this subsection.

Plate 36

36.a. Millipede; *Haraphe* sp.; Xystodesmidae; Polydesmida: C
Seen throughout the year, more common during monsoon. Scavenger.

36.b. Giant millipede; _____; Odontopygidae; Spirostreptida: C
Seen mostly during monsoon; detritivore – feeds on organic matter in leaf litter, also feeds on mushrooms.

36.c. Millipede; cf *Trigoniulus* sp.; Trigoniulidae; Spirobolida: C
Young ones often live in herds; commonly seen during monsoon months.

36.d. Centipede; _____; Scolopendridae; Scolopendromorpha: C
Obligate predators, often found in homes near drainage systems.

36.e. Soil centipede; _____; Geophilomorpha: UC
Long and extremely slender. Underground dwellers; come to the surface occasionally. Seen mostly during monsoon. Hunt small soil-dwelling arthropods.

36.f. House centipede; _____; Scutigeridae; Scutigeromorpha: R
Obligate predators; occasionally seen near homes; prefer dense thickets in wind.

36.g. Pill millipede; _____; Sphaerotheriidae; Sphaerotheriida: UC
Prefer thick leaf litter; detritivorous in nature.

36.h. Woodlouse; _____; Isopoda: C
Commonly seen in groups on moist treebarks; feed on moss, lichens, and other organic detritus.

36.i. Springtail; _____; Collembola; Entognatha: C
Seen in all types of vegetation; often inside homes near damp places. Feed on organic detritus.

Plate 36

14. Insect density of KTR

E. O. Wilson has called insects "the little things that run the world" (Wilson 1987 *in* Rinker and Lowman 2004). And this is reflected in the way they occupy almost any and every available niche. The insects of KTR fill all available niches – from deep underwater and underground where they swim in the waters or tunnel through the soils, to high up in the sky where they fly long distances and on tree canopies where they feed on the foliage; and they consume all the possible food sources available in a variet of ways – from the detritovores consuming the dead leaves shed by trees during early summer and scavengers consuming animal carcass, to herbivores eating green foliage; predators actively hunting other invertebrates; and parasitoids infecting plants and animals. This myriad habit and habitat utilization is crucial in maintaining the equilibrium of an ecosystem; and insects form the nuts and bolts important for its functioning. It is important to understand the insect density along with its diversity when studying their ecology and impact on the ecosystem. It helps in understanding the optimum conditions for their breeding potential, dispersal, as well as chances of population explosion which can be detrimental to other components of an ecosystem, such as plants.

The curious question of which insect is the commonest animal of KTR is fairly easy to answer: ants. If all the ants of the world were weighed, they would weigh as much as humans do, claimed E. O. Wilson. However, their ecological weight is perhaps not as heavy as their actual weight. To explore who weighs more in terms of their impact on the ecosystems as a whole, it is important to study the diversity of insect groups along with their densities. Under the present study, density and abundance studies were undertakn during summer months mainly to understand the assemblages of insects that dwell on the ground during the harsh temperatures of summer.

Density studies were undertaken using quadrat method (*see Sec. 1. Ch. 5.1*). Four distinct vegetation types were selected based on the floral composition (*see Sec. 1. Ch. 5.2*): Sal dominant forests, mixed deciduous forests, bamboo dominant forests, and grasslands. The most common insects recorded on the forest floor were Orthopterans (*Sec. 2. Ch. 8*), followed by Lepidopterans (*Sec. 2. Ch. 1*), Hymenopterans (*Sec. 2. Ch. 7*), Blattodeans (*Sec. 2. Ch. 10*), Dipterans (*Sec. 2. Ch. 6*), Odonates (*Sec. 2. Ch. 9*), and others. Crickets (Orthoptera), were the most abundant individual insects recorded in KTR if ant, termite, and bee colonies are

excluded. The highest density of crickets was an indication that organic detritius is available in abundance, as is reflected in their detritivorous and scavenging habits. This in turn indicates that leaflitter collected on the ground when trees shed their leaves not only provides shelter but also a substratum to feed on, enabling other groups of organisms such as fungi to flourish, and this help return all the nutrients back in the ground. Higher densities of Lepidopterans and Hymenopterans also indicate complex interactions within an ecosystem. Although several of these are pollinators, some are also known to defoliate trees, whereas some are parasitic in nature.

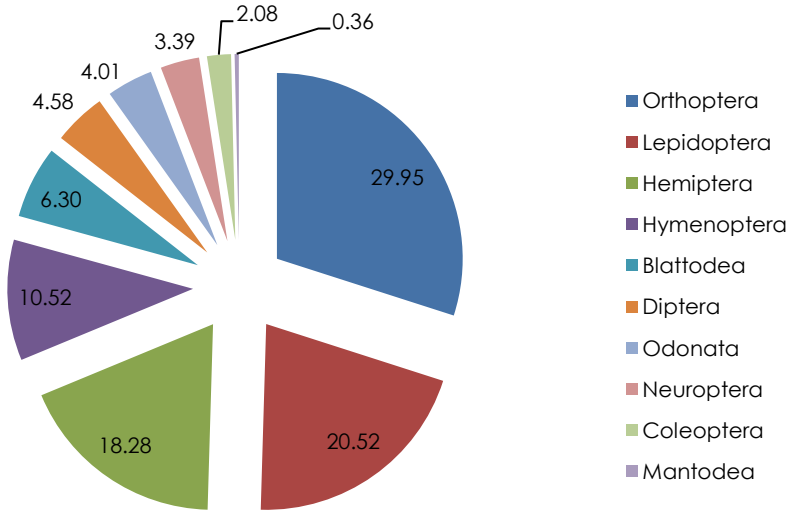


Fig 7. Percent composition of the orders of KTR with high density

Blattodeans (cockroaches and termites) were also high in density which indicates two ecologically important functions – being detritivorous and scavenging in habit, and in their role in degradation of fallen wood to enable nutrient and energy transfer back to earth. High density of Dipterans (true flies) indicates higher decomposition and parasitism (and kleptoparasitism and phoretism) functions which maintain the delicate balance in nature. Odonata is the only group that is an obligate carnivore with a high density – and this crucial factor indicates availability of prey-base. Its relationship to other obligate carnivorous invertebrates however remains unexplored.

Within KTR's four vegetation types, Sal dominant forests were found to be the most diverse as well as densest for insects. These broad-leaved trees are known to

host over 339 insect species in its lifetime (Roychoudhury, Chandra, and Viashy 2012). Mixed deciduous forests showed second highest diversity and density of insects, followed by bamboo dominant forests and grasslands. In terms of social insects such as ants and termites, presence of one was roughly inversely propotional to the presence of the other, probably because of competition for space and food.

The density of insects within the four vegetation types also roughly matched the general insect density trends.

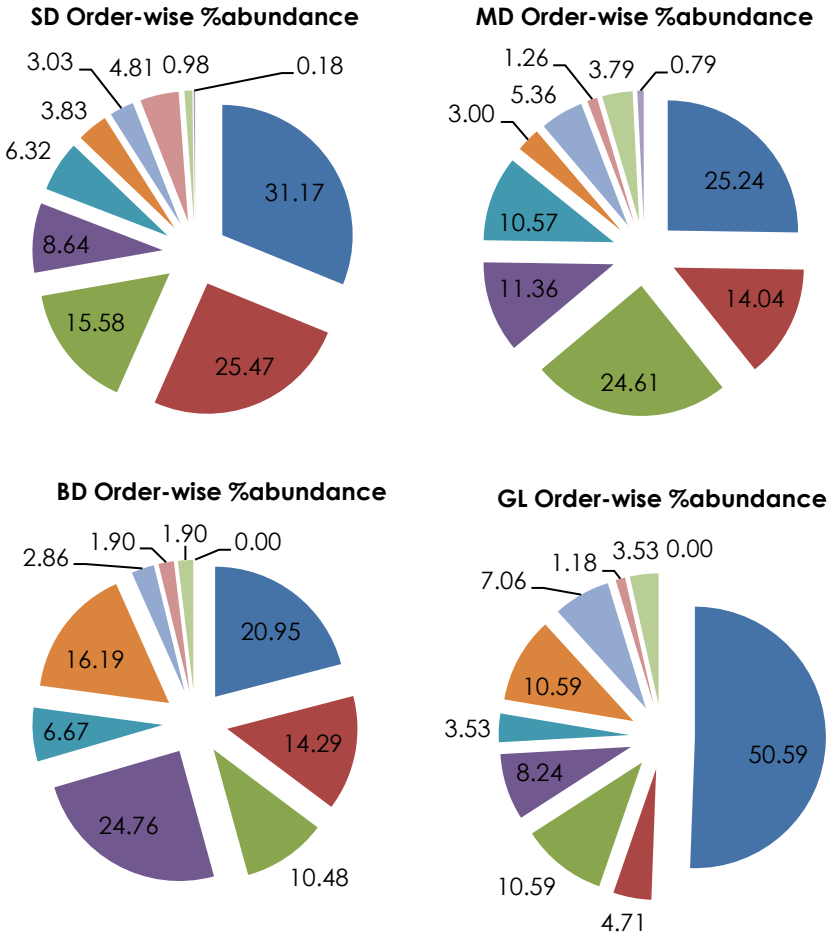


Fig 8. Percent abundance of orders in four vegetation types of KTR. SD = Sal dominant; MD = Mixed deciduous; BD = Bamboo dominant; GL = grasslands. Legends same as Fig 7.

There are several theories put forth to understand the reason behind high abundance and diversity of insects in the tropics, one of the major theories is that the tropics have trees with large leaf-surface area and narrow niches which promote high levels of specialization among insects, especially phytophagous insects (Rinker and Lowman 2004). This is especially reflected in the high density and diversity found in KTR's Sal (*Shorea robusta*) forests which largely remain evergreen throughout the year (except for the short durating when rate of leaffall is greater than new leaf growth), and contains a heavy leaflitter which offers a niche for a number of insects.

Furthermore, Sal forests also provide several other factors such as a rather uniform daily temperature fluctuation, dense leaf litter creating favourable microhabitats, and shade almost throughout all the seasons which make this subtropical forest suitable. Although all these factors are more-or-less observed in all vegetation types, Sal forests offer rather uniform conditions favourable for insects that live on the forest floor. One exceptional group of insects was that of termites (Blattodea; Sec. 10), which occurred more commonly in mixed deciduous forests.

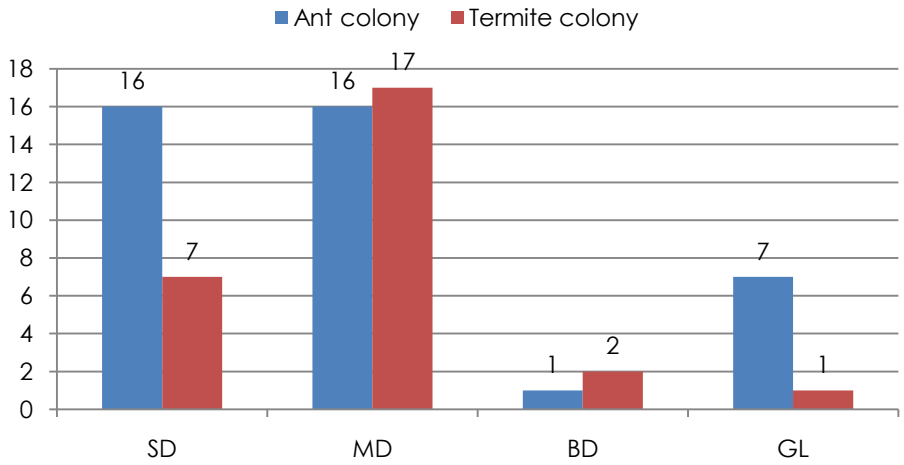


Fig 9. Comparison of ant and termite colonies in the four vegetation types

This could be attributed to the soil type and could be linked with habitat preference of predators such as sloth bears and pangolins.

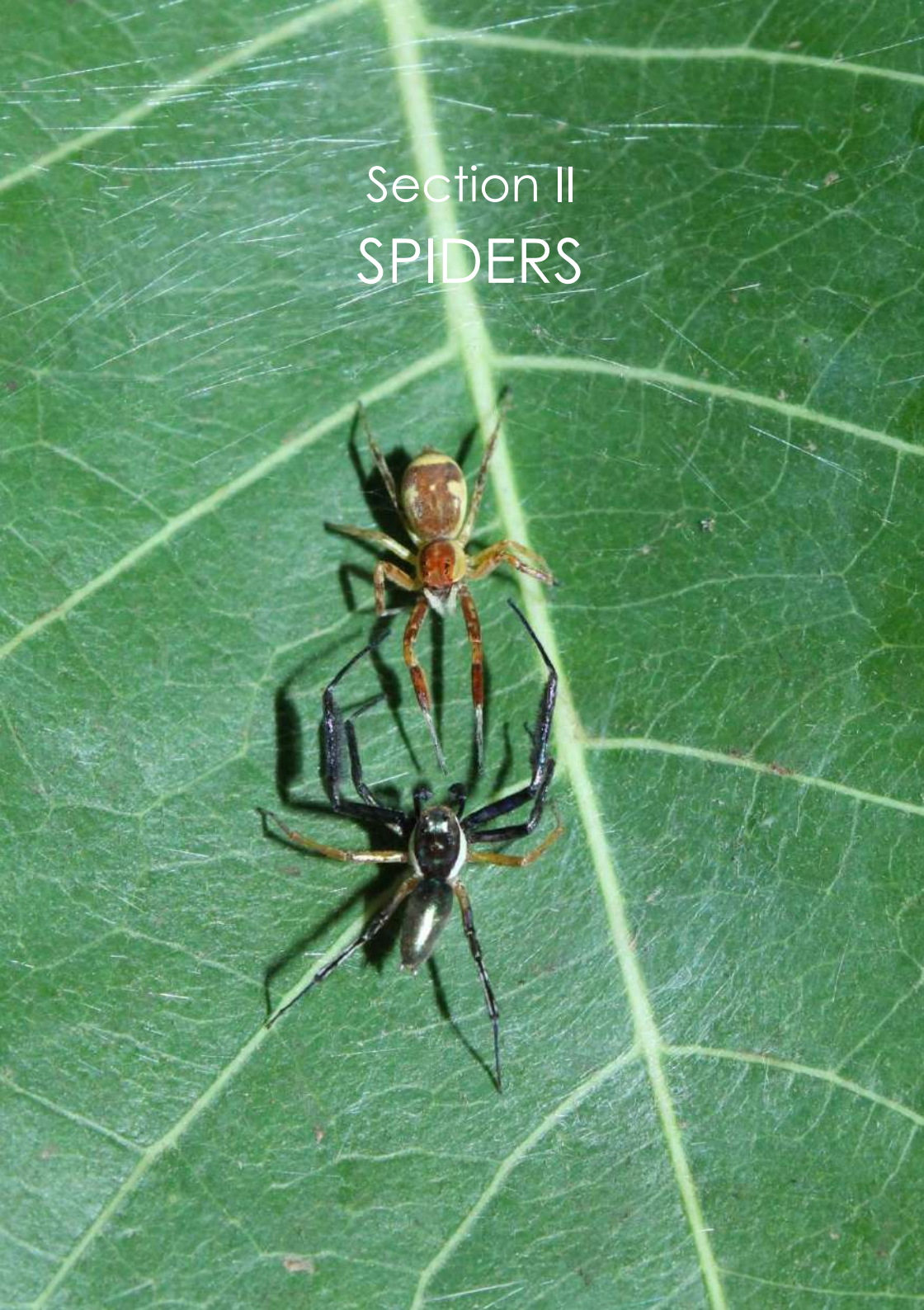
Further studies covering a larger area and all the seasons will provide a concrete understanding of the factors that drive such insect assemblages.

There are several insects which are considered pests or potential pests that could damage the natural integrity of the flora of Protected Areas, such as KTR. Two rather important ones in KTR are the Sal borer beetle (*Ch. 4.2; plate 12*.c) and the bagworm moth (*plate 9.j to 9.l*). Roychoudhary *et al* (2012) have identified *Caviria sericea* (a moth) as a potential pestiferous defoliator on Sal. A suitable example of how such pestiferous insects help forest ecology is that of defoliator insects. Clancy (1994) explains that defoliating insects are often endemic, and have coevolved with the host for thousands of years, and act as "recyclers of nutrients, agents of distmbance, members of food chains, and regulators of the productivity, diversity, and density of plants".

One of the must underlying importances of such assemblages is the genetic diversity. Schowalter (2000) mentions that all populations show variation in genetic composition among individuals and through time, which depends upon factors such as mutation rate, environmental heterogeneity, population size, and mobility. KTR's variety of vegetation types seem to show distinct assemblages, especially during summer season when resources are lowest, which could be a crucial factor in creating a diversity of genetic composition that isolates during such harsh weather, and mingles during suitable weathers such as monsoon. The wild reservoir of KTR's insect diversity could therefore be significant for migratory insects such as some Danaine butterflies (such as Blue Tiger; *plate 2.d*), and dragonflies (Wandering Glider; *plate 30.c*), as well as that of biocontrol agents which are yet to be discovered.

Plants influence, and get influenced by, insects in a sort of a coevolutionary dance (Rinker and Lowman 2004). One of the direct outputs of insects to an ecosystem is in the form of insect fecies, called frass. Rinker and Lowman (2004) metion that frass plays a significant role in nutrient cycling, which may often exceed annual litterfall inputs, and forms a major product that feeds decomposers on the forest floor and in turn nourish the forest.

The density and diversity of insects is further influenced by, and influences, the animals that depend upon them. In the next section, the most significant invertebrate predator of insects, the spider, is discussed.



Section II
SPIDERS

1. Introduction

Spiders belong to one of the largest group of invertebrates, Class Arachnida, and are placed in their own Order Araneae. They are the most diverse order of Arachnida, and are characterized by presence of four pairs of legs, a cephalothorax containing a head with eight eyes, mouthparts, and the thorax, and an abdomen connected to the cephalothorax by a pedicel. They breathe through a pair of book lungs which upen on the underside of the abdomen. A spider's most special characteristics are the ability to spin silk through openings at the posterior tip of the abdomen called spinnerets, and presence of venom glands connected to hollow fangs.

Spiders undergo a typical lifecycle: from an egg to an adult; however their lifecycle is rather varied, and many exhibit different behaviours. Typically, females lay eggs in a cluster – some lay it under the surface of leaves, some build egg-sacs which contain several hundred eggs – there is diversity even among the shape and size of eggsac and egg numbers amongst families and species. Most spiders show parental care: females guard eggs until the first moulting. Young ones of spiders are called spiderlings, and they feed on small invertebrates soon after leaving the protective care of their mothers. Some spiders, such as Wolf spider (Lycosidae), carry their young ones onto their abdomens until the first moult, after which the spiderlings lead an independent life. They moult several times to reach an immature stage where they appear like adults but are not sexually mature. Adult spiders lead an independent life, but are often found in close proximity if food resource is abundant. Very few spider species show actual social behaviour, such as Social spiders (Eresidae), which build a common web in which several spiders live and hunt as a single unit. Reproduction amongst spiders is rather complex, males are easier to tell from females by the presence of specialized palps which are located near the mouth. They have a distinct club-like appearance which is lacking in females, and use it to transfer sperms to females. Reproduction in spiders is rather complex, males involve in intricate courtship dances to entice females, and males have to be rather weary while approaching females so that they are not treated as prey. Courtship display and dance is well known amongst Jumping spiders (Salticidae), spiders such as Giant wood spiders (Nephilidae) show distinct sexual dimorphism – males are extremely small and red in colour, while females are very large, and build the intricate, giant orb-webs we often see during monsoon. The males usually remain along the periphery of the female web, and use distinct undulations in the web to alert the female that he is a male and not prey.

Spiders are obligate carnivores, and occupy all the possible niches where insects and other invertebrates are found – the major part of their diet. Almost all species of spiders use silk in various forms, as draglines, webs, traps, and in wrapping of prey for immobilization. Most spiders are also venomous, and inject venom into the captured prey by piercing their fangs. Spiders do not feed on solid food, but use their venom and digestive enzymes to dissolve the inner parts of their prey, and then suck the liquid through their mouth.

There are a number of ways in which a spider captures its prey; most use their silk in a number of ways, while some only use it as draglines. Among web-builders, the most common are orb-weavers (Araneidae), giant wood spiders (Nephilidae), and orchard spiders (Tetragnathidae). They build intricate, orb-shaped webs ofte between two branches or plants, and wait in the middle for flying insects to get trapped in. Some build tangled webs (also called cobwebs), which appear haphazard and, in a way, untidy. These are mostly built by daddy long legs (Pholcidae) and comb footed spiders (Theridiidae) in nooks and corners of trees and also houses. Very few spiders build specialized webs, *Theridula* spiders of Theridiidae builds gumfoot webs, which are long pillars of very sticky web suspended form underneath a leaf under which a spider rests. These pillars act as traps for flying insects, and the spider uses a special non-sticky web to drop down to the prey and covers it in silk. *Deinopis* spider in the family Deinopidae has a rather unique way of capturing prey. They capture prey using a net which roughly resembles fishing net. The spider stays suspended upsidedown from a plant, and holds the stretched net in its forelimbs. When an insect passes from under, it pounces upon it and entangles it in the net. Spitting spiders (Scytodidae) build very basic webs by foldin a leaf together; they rest here for most of the day and hunt during the night. They have modified venom glands which are used to eject a sticky mass of venom and silk to entrap prey. Tunnel-sheet spiders (Lycosidae) build tunnels and contain a verandah of sticky web in front of the tunnel where the spider lurks. When an insect such as a grasshopper becomes stuck on this sheet of web, the spider quickly envonamates it, wraps it, and takes it inside its tunnel to feed upon it. Several spiders such as Jumping spider (Salticidae), Wolf spider (Lycosidae), Wandering spider (Ctenidae), Huntsman spider (Sparassidae), Water spider (Pisauridae), Two tailed spider (Hersilidae) and Dark sac spider (Corinnidae) are freeranging spiders – they do not build a web or ambush their prey, but actively hunt for prey in the leaf litter or on trees. They only use draglines to remain bound to a place or use it for controlled jumping, in such spiders, web is only built for creating a nursery for laying eggs, during moulting, or to creat a protective eggsac around a mass of eggs. Some small spiders and spiderlings use webs in another way to travel long

distances, called ballooning or kiting. After finding a suitable perch, the spider sends out a long, thin line of silk into the air, and once it catches the aircurrent, it carries the spider long distances. This is often encountered during monsoon or post-monsoon months, sometimes these balloon webs randomly stick to our faces in the open.

At least seven types of silks are used by spiders, each having different properties of strength and flexibility; however, we still don't know how exactly do spiders measure the strength of their silk; for instance, giant wood spiders build largest orb-webs, and their silk is said to be strongest amongst spiders, however it is unknown how the spider herself judges how strong the silk should be – a little stronger and the prey would bounce off the web like a ball; a little weaker and the prey will pass through the web creating a hole in it. Some spiders also construct a web called stabilimenta within their larger webs, which are hazy in appearance. Such webs are commonly used by Signature spiders (Araneidae), and are probably used to attract prey or to deter birds from flying into their web and damage it.

Spiders use camouflage to hide from predators as well as to capture prey. Most are cryptic in appearance to blend into the foliage by mimicking branches, barks, and leaves; some species are rather vividly coloured but the purpose of their aposematic colouration is rather unclear. It is perhaps used to attract females, who are generally drab or dull in colour to avoid being targeted by predators. Spiders such as Lynx spider (Oxyopidae) and Crab spider (Thomisidae) often mimic the colours of leaves and flowers where they lie in ambush for insects visiting flowers. Spiderlings are usually pale or dark in colour, and their adult colour is not attained until they reach maturity.

Spiders are a rather important component of an ecosystem, and are used as indicators of the health of an ecosystem. Presence of spiders in high density signifies a steady and large resource of prey base, and their high diversity signifies a healthy prey base as well as availability of various niches within an ecosystem. Perhaps their most direct use for humans is in controlling population of pestivorous insects in agricultural fields and food storage units. Scientists are now working on rearing and release of spiders in agricultural fields to control insect populations, since they feed on a wide range of insects unlike host-specific parasitoids and predators which attack only a certain species. Spiders are also being studied in detail for their use of silk, a complex protein that can expand, contract, stretch, and yet remain stronger than most metals we use. Scientists are engaged in

creating synthetic spider silk for its uses in medicine, clothing, and in mechanical processes because of its high tensile strength.

About 45618 species of spiders have been recorded worldwide belonging to 110 families (World Spider Catalog 2015). Keswani, Hadole and Rajoria (2012) have listed 1686 species from 60 families from India, and several new species are being discovered every year. The most diverse family of spiders in India (with >100 species) is that of Jumping spiders (Salticidae), orb-weavers (Araneidae), crab spiders (Thomisidae), Ground spiders (Gnaphosidae), and wolf spiders (Lycosidae) (Keswani et al 2012). Spider diversity in Madhya Pradesh and Chhattisgarh was studied by Patil (2011), who recorded 214 species in 22 families. An additional family Stenochilidae is also recorded by Vyas and Shirbhate (2012). Studies on spiders of KTR were done by Gajbe (1995) who recorded 14 species; there have been no studies pertaining to spiders in KTR since. Gajbe (2004) also recorded 107 species belonging to 19 families from Jabalpur district, which was later updated by Patil (2012) to 117 species in 20 families. Rithe (2012) recorded 254 species in 27 families from Melghat Tiger Reserve, a reserve in central India.

No spiders are protected under India's Wildlife Protection Act 1972, although there are several species of spiders known to be endemic to a very small area, such as the Gooty Tarantula *Poecilotheria metallica* (listed as Critically Endangered in IUCN Red List). Incidences of poaching of tarantula spiders as pets, although unrecorded, are also noted from India. Anthropogenic pressures such as grazing, habitat degradation and fragmentation, along with poaching, are major activities threatening spiders.

Knowing spider diversity is crucial for ecological planning, especially with regards to microhabitats and pest management, since spiders often indicate several aspects of the basic functions of an ecosystem: spiders are extremely sensitive to small changes in habitat structure, including vegetation complexity, litter depth and microclimate characteristics, furthermore their high relative abundance and diversity in habitat preferences and foraging strategies allows for effective monitoring of site differences (Uetz 1991 and Yen, 1995, cited in Hore and Uniyal, 2008 p. 1371). Hence, spiders have been proposed as indicator species (Churchill 1998; Sebastian and Peter 2009).

2. Observations

Spiders often go unnoticed in Protected Areas (PA) because they do not draw the attention of a regular tourist, however studies on spider diversity of PAs is considered important scientifically, and such studies have been undertaken in various PAs, cities, states, and landscapes and ecosystems of India, some of which include: spiders of Terai Conservation Area (Uniyal and Hore 2009), spiders of the state of Kerala (Jose 2005), spiders of Madhya Pradesh and Chhattisgarh (Gajbe 2002; Patil 2011), spiders of Tornamal Sanctuary in Maharashtra (Meshram 2011), spiders of Jabalpur district (Patil 2012), spiders of Shekhawati Aravalian region in Rajasthan (Saini, Chauhan, and Singh 2012), spiders of IISc Bangalore in Karnataka (Nalini, Ravindranatha 2012), spiders of cashew agro-ecosystems (Bhat, Shrikumar, and Raviprasad 2013), spiders of Radhanagri Chandoli and Koyana Wildlife Sanctuary in Maharashtra (More and Sawant 2013), spiders of Koeladeo National Park in Rajasthan (Kaur *et al* 2014), spiders of Narmada River near Rajghat in Madhya Pradesh (Sharma, Vyas, and Sharma 2010), spiders of Gibbon Wildlife Sanctuary in Assam (Chetia and Kalita 2012), and many more studies are currently being undertaken in India that focus on spider diversity. Most of such studies however seldom catch the interest of the residents and visitors, and hence building the interest and inspiring others to understand spiders as a part of one ecosystem becomes difficult. This section tries to bridge the gap between the field of taxonomy and awareness concerning spiders of KTR.

A total of 114 individual spider specimens were recorded during the present study belonging to 23 families. About 33 specimens have been tentatively identified upto species-level, 80 have been tentatively identified upto genus-level, and one remains identified only upto family-level. Nine non-spider arachnids are also reported here: 3 scorpions, 2 pseudoscorpions, 1 harvestman, 1 tick, and 2 velvet mites. With respect to the present study, Salticidae is represented by the highest number of species, followed by Araneidae, Thomisidae, and Lycosidae. The rare spiders belong to Deinopidae and Oonopidae, however their rarity is largely because of their inconspicuous appearances.

The highest summer density of spiders of KTR is that of the Lynx spider (*Oxyopes* cf *javanus*; Oxyopidae), followed by Wolf spider (*Lycosa* sp.; Lycosidae), and Jumping spider (*Stenaelurilus* sp.; Salticidae), followed by members of Araneidae (True orbweavers), Thomisidae (Crab spiders), and Theridiidae (Comb footed spiders). As seen for the density of insects, Sal dominant forests contain the highest density and diversity of spiders, followed by mixed deciduous forests,

bamboo dominant forests, and grasslands. This trend is typically observed during summer months because of restriction of movement during the harsh drier months, scarcity of insects (primary food source), as well as effect of temperature and humidity.

This section discusses 114 spiders belonging to 23 spider families in detail along with four non-spider arachnid orders, and contains information on their habitat utilization and natural history as was observed during the study.

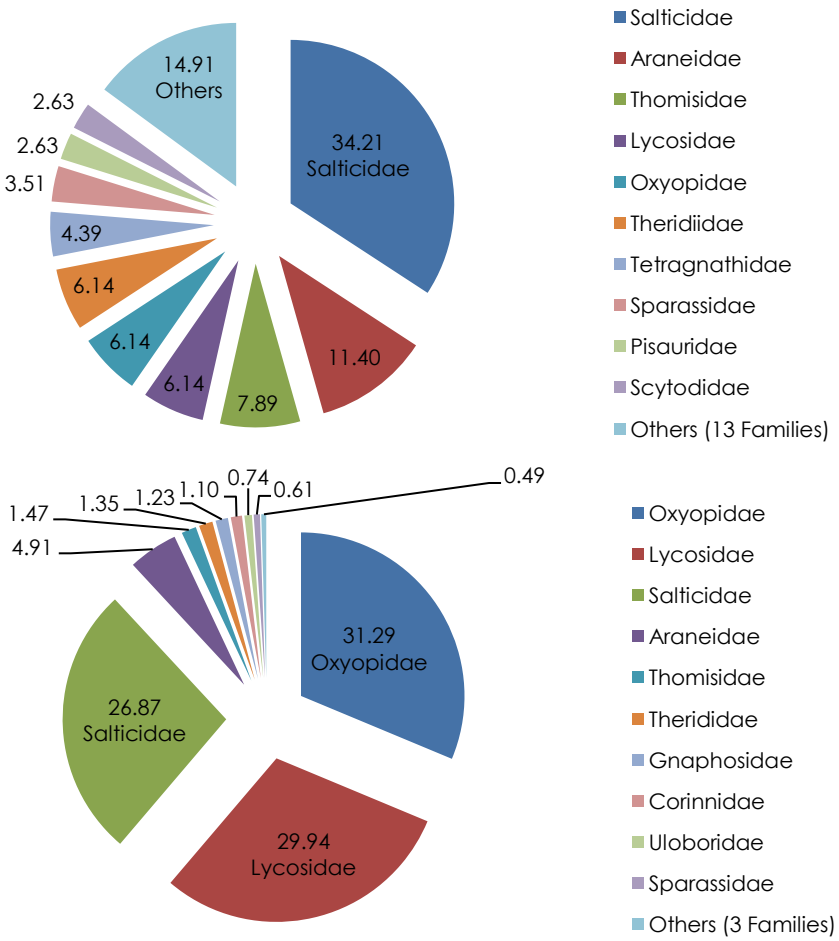


Fig 10. Species-wise %composition of spider families (top); Density-wise %composition of spider families of KTR (above).

3. Araneae

Araneus = spider; *eae* = group

Spiders are placed in order Araneae under class Arachnida. Of the 60 families recorded in India, 26 have been recorded in KTR. This chapter focuses on 23 families recorded under the present study. Subchapter 3.1 to 3.10 focuses on spiders that make minimum use of silk for hunting; 3.11 to 3.19 use silk but do not build the intricate orb-webs, and 3.20 to 3.23 focuses on spiders that build orb webs; following this is a picture plate showing the eye-patterns of 18 families which can be observed using a macro-camera or a hand-lens (*plate 37*). The later part of this chapter contains picture plates of 114 spiders classified according to their family/genus/species with information on their ecology in KTR.

3.1 Salticidae (Jumping spider) (*Plate 37.a*)

Jumping spiders are small (<2cm), robust built freeranging spiders known for their typical jumping movement. They are the most diverse families of spiders inhabiting a wide array of niche – from the forest floor to high up in the canopy, in agriculture fields as well as at homes. They mainly prey on small insects. Some species show distinct sexual dimorphism; some are cryptic in colour and habit.

3.2 Lycosidae (Wolf spider) (*Plate 37.b*)

Wolf spiders are ground-dwelling freeranging spiders of varying sizes (>1cm to 5cm) who hunt other insects and invertebrates. Several species build tunnel-like webs on the ground and remain stationary, relying on ambush rather than active hunting. They are most common on forest floor and grasslands, and are important pest controllers in agricultural fields.

3.3. Ctenidae (Wandering spider) (*Plate 37.c*)

Wandering spiders are ground-dwelling freeranging spiders of varying sizes (>1 to 4cm) similar in appearance of wolf spiders, and share the same habit and habitat with them. Some large species are known to prey on wolf spiders. They are mostly nocturnal and more commonly observed during monsoon months.

3.4 Sparassidae (Huntsman spider) (*Plate 37.d*)

Huntsman spiders are probably the largest spiders of KTR, some measuring over 10cm. They are also freeranging spiders inhabiting boulders, man-made walls, trees barks, and are active hunters. Most species are cryptic in colouration however several are vividly coloured. They are mostly nocturnal and especially common near lights at night to prey on insects.

3.5 Pisauridae (Nursery web spider) (*Plate 37.h*)

Nursery web spiders are solitary medium-sized (>2cm-4cm) spiders commonly seen near wetlands, with some species specializing in hunting underwarer fishes, tadpoles, and aquatic insects. They are especially common during monsoon months, and are often seen floating close to the banks of still waters or in the nearby grasses. Some species are freeranging in habit, and may be seen near lights at night preying upon insects.

3.6. Hersilidae (Two tailed spider) (*Plate 37.e*)

Two tailed spiders are medium sized, freeranging spiders commonly found on treetrunks, often on moss and lichen-laden man-made walls. They have a rather small rounded body but extremely long legs, making them as large as 10cm in length from one tip to the other tip of the leg. They are active hunters and prey upon insects that dwell on tree barks. They have cryptic colouration and quick in movement, making it rather hard to find them.

3.7. Gnaphosidae (Ground spider) (*Plate 37.k*)

Ground spiders are freeranging, small spiders (<1cm to 2cm) often dark brown to black in colour. They are rather easily identified by the presence of two cylindrical spinnerets at the end of their abdomen. They live in leaf litter but are often found at homes on the floor. They are active hunters and nocturnal in nature.

3.8 Corinnidae (Dark sac spider) (*Plate 37.g*)

Dark sac spiders are freeranging, dark coloured small (<2cm) spiders which appear much like Camponotus ants (*Plate 21.a*), and even mimic the walking style of these ants. They are most common during pre-monsoon showers when they are seen on the forest floor, and often enter homes.

3.9. Oxyopidae (Lynx spider) (*Plate 37.f*)

Lynx spiders are small (<2cm) ambush hunters that lie in wait of a passying prey usually on flowers, leaves or on leaf litter. They have distinct thorny legs unlike most other spiders and a squarish cephalothorax. They are the most abundant spiders of KTR, inhabiting all vegetation types.

3.10. Thomisidae (Crab spider) (*Plate 37.i*)

Crab spiders are small (<1cm) ambush hunters that lie in wait of a passing prey usually on flowers, branches, and leaf litter. They distinctly hold their front two pair of legs like the chelicerae of crabs, hence the common name. Most species are triangular in shape, and contain horn-like projections on the hea upon which eyes are set. Some are also extremely cryptic in appearance to match the colour of flowers, leaves, and the earth.

3.11 Pholcidae (Daddy long legs) (*Plate 37.j*)

Daddy long legs are small spiders with extremely long, thin legs (reaching <5cm in length), commonly found in dark coners of rocks, tree hollows, and are most commonly seen spiders at homes. They build cobwebs which are efficient at capturing flying insects such as flies and mosquitoes. In presence of a good food source, they are commonly observed living in close proximity to one another.

3.12 Oecobiidae (Disc web spider)

Disc web spiders are extremely small (<0.5cm), solitary spiders that seldom leave their typical "disc" shaped webs. They are very common in homes where they build their webs along corners of the walls, especially near a light source where they feed on tiny insects.

3.13 Scytodidae (Spitting spider) (*Plate 37.l*)

Spitting spiders appear similar to daddy long leg spiders except for an elongated and steeply sloped cephalothorax and a round abdomen. They have long legs and can reach the length of <4cm. They are solitary, freeranging spiders but seldom wander far from their daytime retreats. They are most commonly observed during monsoons when they build nests by folding a leaf. They hunt by ejecting a stick mass of venom and silk from modified venom glands.

3.14 Eresidae (Velvet spider) (*Plate 37.m*)

Velvet spiders are medium-sized (>2cm) solitary spiders only seen during monsoon months when they build a nest comprising of several leaves bound haphazardly together by a strong, sticky silk. Sometimes a ladder-like web is constructed onto nearby leaves. They have a hump-like cephalothorax and an elongated abdomen. They rest in a small tunnel of web created with the leaves and lie in wait of passing prey. Some species are known for their social behaviour, however social spiders were not recorded in KTR.

3.15 Stenochilidae

These spiders lack a common name, and are extremely small in size (<1cm), dark red in colour, and live underground or usually under rocks in a thin tunnel.

3.16 Clubionidae (Sac spider) (*Plate 37.p*)

Sac spiders are medium sized (<2.5cm) pale whitish yellow coloured spiders with a reddish part near eyes and mouth, with long legs and an elongated abdomen. They are mostly nocturnal, and build thin webs often by folding leaves together during day time. They are commonly found in forested areas.

3.17 Deinopidae (Net casting spider) (*Plate 37.n*)

Net casting spiders are rather long (<5cm) but extremely thin solitary spiders relying on ambush for catching prey. They are distinctly told apart from other spiders by the presence of the largest simple eye (oecli) of all invertebrates. Females are rather broad in appearance than males. They are most commonly observed in dense thickets during monsoon months. They are nocturnal in nature, hunting using a specialized fishing net-like web to entrap prey. During daytime, they remain still to appear like dry twigs.

3.18 Oonopidae (Dwarf hunting spider)

Probably the smallest spiders of KTR (<0.5cm) they usually live in a small group under the bark of trees. They are red in colour, contain large eyes for their size, and prey upon small invertebrates that dwell on treetrunks.

3.19 Theridiidae (Comb footed spider)

Comb footed spiders, also called cobweb spiders, are small solitary spiders (<1cm to 2cm) showing most diverse ways of hunting. Some species build cobwebs in moist places including corners of homes, some build intricate gumfoot webs, whereas some are kleptoparasites of other spiders, where they steal food captured by larger spiders such as giant wood spider and signature spiders.

3.20 Uloboridae (Hackled orbweaver)

Hackled orb weavers are small (<1cm) spiders building rudimentary orbwebs with randomly shaped stabilimenta. They can be told apart from other orbweavers by the presence of thickened first pair of legs which are usually held straight in front of the eyes. They are the only nonvenomous spiders of KTR, and rely on their cribellate silk which contains many strands to entrap their prey. They are most common in thickets, but are also see nesting under ledges of walls or near lights.

3.21 Tetragnathidae (Long jawed orbweaver) (*Plate 37.o*)

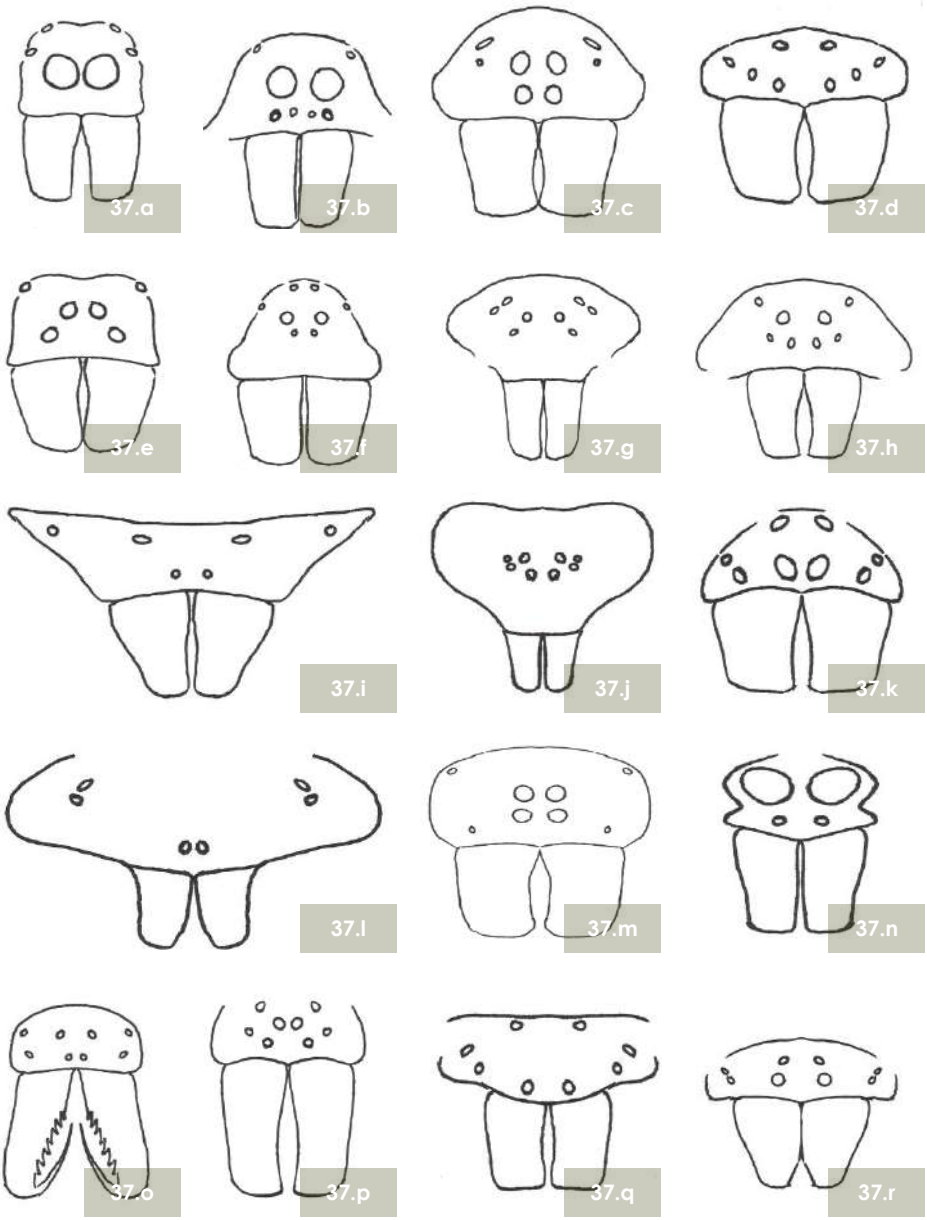
Long jawed orb weavers are slender, elongate spiders (>2cm) building horizontal orbwebs near wetlands and even near moist places around houses. They posses elongated fangs (hence the common name). Some species such as Orchard spiders lack the long fangs but show the typical horizontal or slanting orbwebs.

3.22 Nephilidae (Golden orb spider) (*Plate 37.q*)

Golden orb spiders, also called giant wood spiders are one of the largest spiders of KTR (>7cm). Adult females are known for building some of the largest webs amongst spiders, and are a common sight during post-monsoon and early winter months. The males are rather small (<2cm), orange in colour and are seen along the periphery of a female's nest, with as many as 7 males observed on one nest. They feed on large insects that get trapped in their sticky webs, and usually construct or repair their webs at night. Spiderlings build small orbwebs by June.

3.23 Araneidae (True orbweaver) (*Plate 37.r*)

True orbweavers are medium sized (<3cm) spiders very common and diverse in their habits – some build the typical orb-shaped webs, some decorate it with stabilimenta, whereas some collect debris in their orbwebs and few build dome-shaped webs. They are the second most diverse family of spiders in KTR.



Note: Eye-patterns are unique for ever family. The eye patterns shown here are generalized schematic drawings of some of the common members of a certain family. They roughly change from species to species, but the overall patternof eye-arrangement remains more-or-less the same.

Plate 37

Plate 38

38.a. Jumping spider; *Carrhotus viduus* Male; Salticidae: C

Mostly seen during monsoon, uncommon during dry seasons; found in shrub habitats and forest edges. Prefers above ground foliage.

38.b. *Carrhotus viduus* Female; Salticidae: C

38.c. *Carrhotus sannio*; Salticidae: UC

Occasionally seen on forest floor.

38.d. *Hyllus semicuperus* Male; Salticidae: C

Mostly arboreal. Largest jumping spider of KTR. Often seen on low shrubs and lower canopy of trees.

38.e. *Hyllus semicuperus* Female; Salticidae: C

38.f. cf *Ptocasius yashodharae*; Salticidae: UC

Occasionally seen on tree barks, also seen on walls. More common in monsoon.

38.g. *Menemerus bivittatus* Male; Salticidae: C

Often seen on walls and tree trunks (especially Mahua), most common during pre-monsoon and monsoon months on walls.

38.h. *Menemerus bivittatus* Female; Salticifae: C

38.i. *Stenaelurillus* sp.; Salticidae: C

Most common jumping spider of KTR. Prefers forest floor with dense leaf litter. Common in all seasons; spiderlings mostly seen during summer and monsoon.

38.j. *Telemonia dimidiata* Male; Salticidae: C

Mostly arboreal; commonly seen on trees mostly in gardens and forest edges.

38.k. *Telemonia dimidiata* Female; Salticidae: C

38.l. *Asemnoea* sp. Male; Salticidae: UC

Mostly arboreal; male uncommon than female.

38.m. *Asemonea tenuipes* Female; Salticidae: C

Mostly arboreal, often seen resting under the shade of Tendu leaves.

38.n. *Asemonea* sp. Female 1; Salticidae: C

Female of an unknown species, note the colour difference after moulting in 38.o.

38.o. *Asemonea* sp. Female 1 (after moulting); Salticidae: C

Plate 38

Plate 39

39.a. *Harmochirus brachiatus*; Salticidae: C

Small spider, mostly seen in leaflitter, often found in gardens.

39.b. *Marengo* sp.; Salticidae: C

Mostly arboreal; commonly seen on trees mostly in gardens and forest edges.

39.c. *Marengo* sp.; Salticidae: C

Mostly arboreal; often seen on trees in all types of ecosystems.

39.d. *Rhene danieli*; Salticidae: C

Mostly arboreal on shrubs; often seen on trees in all types of ecosystems.

39.e. *Rhene flavigera*; Salticidae: C

Mostly arboreal on shrubs; often seen on trees in all types of ecosystems.

39.f. *Rhene* cf *rubrigera*; Salticidae: C

Mostly arboreal but also found on ground; often seen on trees in all types of ecosystems.

39.g. *Rhene* sp. _____; Salticidae: C

Mostly arboreal on shrubs; often seen on trees in all types of ecosystems.

39.h. *Rhene* sp. _____; Salticidae: C

Mostly arboreal on shrubs; often seen on trees in all types of ecosystems.

39.i. *Rhene* sp. _____; Salticidae: C

Mostly arboreal on shrubs; often seen on trees in all types of ecosystems.

39.j. *Plexippus paykulli* Male; Salticidae: C

Commonly seen around houses, mostly seen on treebarks and leaflitter.

39.k. *Plexippus paykulli* Female; Salticidae: C

39.l. *Plexippus petersi* Male; Salticidae: C

Not as common as P. paykulli; mostly seen in leaflitter.

39.m. *Plexippus* sp. _____; Salticidae: UC

Only noted once on a wall.

39.n. *Yaginumaella* cf *aishwaryii*; Salticidae: C

Found in dark and damp places, especially marshy areas.

39.o. *Thyene* sp. _____; Salticidae: C

Mostly arboreal; often seen on trees in all types of ecosystems.

Plate 39

Plate 40

40.a. *Chrysilla* sp. _____ Male; Salticidae: C

Mostly seen on forest floor or understory of forests.

40.b. *Chrysilla* sp. _____ Female; Salticidae: C

40.c. *Phintella* sp. _____; Salticidae: C

Small spider arboreal in nature, mostly found on small trees, especially common on Tendu.

40.d. *Epeus indicus*; Salticidae: C

Mostly arboreal; often seen on trees in all types of ecosystems.

40.e. *Epocilla* sp. _____ Female; Salticidae: UC

Strictly arboreal; seen near forested areas around wetlands.

40.f. *Hasarius adansoni* Male; Salticifae: C

Often seen on forest floor or on walls; rather common near human settlements.

40.g. *Phlegra* sp. _____; Salticidae: C

Often seen on forest floor.

40.h. Ant mimicking jumping spider; *Myrmarachne plateloides* Male; Salticifae: C

Mostly arboreal; often seen close to Weaver ants (*plate 21.e*).

40.i. Ant mimicking jumping spider; *Myrmarachne* sp. _____; Salticidae: C

Often seen in close proximity to ants. Resembles *M. brunnea* ant (*plate 22.a*)

40.j. *Myrmarachne* sp. _____; Salticidae: C

Often seen in close proximity to ants. Resembles *M. criniceps* ant (*plate 21.k*)

40.k. *Myrmarachne* sp. _____; Salticidae: C

Often seen in close proximity to ants. Resembles T. rufonigra ant (plate 22.c)

40.l. *Myrmarachne* sp. _____; Salticidae: C

Often seen in close proximity to ants. Resembles *Crematogaster* ants (*plate 21.i*)

40.m. *Myrmarachne* sp. _____; Salticidae: C

Often seen in close proximity to ants. Resembles *Camponotus* ants (*plate 21.a*)

40.n. *Myrmarachne* sp. _____; Salticidae: C

Often seen in close proximity to ants. Resembles *C. sericeus* ants (*plate 21.b*)

40.o. *Myrmarachne* sp. _____; Salticidae: C

Often seen in close proximity to ants. Resembles *Camponotus* ants (*plate 21.a*)

Plate 40

Plate 41

41.a. *Brettus* sp. _____ Male; Salticidae: C

Mostly arboreal, common during monsoon.

41.b. *Brettus* sp. _____ Female; Salticifae: C

Mostly arboreal, more commonly seen than male.

41.c. *Brettus* sp. _____ Female after moulting; Salticidae: C

Females and males both show distinct colouration after the final moulting.

41.d. *Portia* cf *albimana*; Salticidae: UC

Mostly arboreal, seen only during monsoon. Known to hunt other spiders but also feeds on alate termites.

41.e. *Cyrba* sp.; Salticidae: R

Prefers forest floor, observed only once.

41.f. Wolf Spider; *Lycosa mackenziei*; Lycosidae: C

Strictly ground dwelling; found in large numbers in near sandy banks of wetlands.

41.g. *Lycosa* sp. _____ Female carrying egg sac; Lycosidae: C

Strictly ground dwelling; found in large numbers in forests with dense leaf litter

41.h. Wolf Spider; *Evippa* sp. _____; Lycosidae: C

Largest wolf spider of KTR; ground dwelling; nocturnal in nature.

41.i. *Evippa* sp. burrow; Lycosidae: C

Evippa sp. make circular burrows lined with silk, entrance is always open. Seek shelter during daytime.

41.j. cf *Schizocosa* sp.; Lycosidae: UC

Ground dwelling; distinct white tufts of hair on forelegs; seen during monsoon.

41.k. Wolf Spider; *Pardosa* sp. _____; Lycosidae: C

Ground dwelling, prefers dense leaf litter.

41.l. Wolf Spider; *Trochosa* sp. _____; Lycosidae: C

Ground dwelling, prefers dense leaf litter.

41.m. Tunnel sheet spider; *Hippasa* sp. _____; Lycosidae: C

Makes sheet webs on slightly sloping ground, mostly near roots of large trees. Spider lies in ambush in a tunnel built roughly on one side of the sheet.

41.n. *Hippasa* sp. _____; Lycosidae: C

41.o. *Hipassa* sp. _____; Lycosidae: C

Plate 41

Plate 42

42.a. Wandering spider; *Ctenus* sp. _____; Ctenidae: C

Ground dwelling spider; nocturnal in nature; mostly found in forest undergrowth.

42.b. *Acantheis* sp. _____; Ctenidae: C

Ground dwelling spider; nocturnal in nature; mostly found in forest undergrowth.

42.c. Huntsman spider; *Heteropoda venatoria* Male; Sparassidae: C

Largest spider of KTR; prefers large trees or walls; nocturnal in nature; common around homes and especially near lights at night to hunt insects.

42.d. *Heteropoda venatoria* Female; Sparassidae: C

42.e. Green huntsman spider; *Olios milleti*; Sparassidae: C

Ground dwelling spider; nocturnal in nature. Rests in a folded leaf during day.

42.f. *Olios* sp. _____; Sparassidae: C

Similar in habit as *Olios millet*.

42.g. cf *Thelcticopis* sp. _____; Sparassidae: UC

Mostly ground dwelling spider; nocturnal in natue, rests in crevasses during day.

42.h. cf *Thelcticopis* sp. _____ Eye pattern; Sparassidae

42.i. Water spider; *Thalassius* sp. _____; Pisauridae: C

Common during monsoon near still water bodies such as puddles, ponds, and lakes. Floats close to edge of water to hunt aquatic insects, fishes and tadpoles.

42.j. Nursery web spider; *Perenethis* cf *unifasciata*; Pisauridae: C

Common during monsoon and summer; mostly found close to still water bodies, however do not float over water but remain in the nearby grasses and herbs.

42.k. *Dendrolycosa* sp. _____; Pisauridae: C

Large spider building broad sheet web containing a tunnel at the edge. Unlike *Hippasa* sp. (*Plate 41.m*), builds web above the ground as high as 15 feet.

42.l. Two tailed spider; *Hersilia* sp. _____ Male; Hersilidae: C

Tree bark dweller, common on virtually all older trees, however not observed often because of camouflage. Hunts ants and other tree-bark dwelling invertebrates.

42.m. *Hersilia* sp. _____ Female; Hersilidae: C

42.n. Ground spider; *Scotophaeus* sp. _____; Gnaphosidae: C

Ground dwelling spider; nocturnal; mostly found in forest undergrowth and human habitations.

42.o. Dark sac spider; *Casitaneria* sp. _____; Corinnidae: C

Ground dwelling spider; mimics Camponotus ant (*Plate 21.a*) common in all habitats including human habitations.

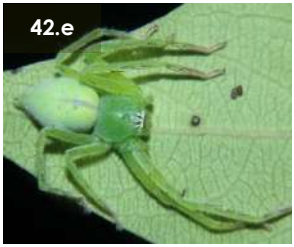


Plate 42

Plate 43

43.a. Lynx spider; *Oxyopes* cf *javanus* Male; Oxyopidae: C
Most common spider of KTR; mostly found on forest floor or on low herbs.

43.b. *Oxyopes* cf *javanus* Female; Oxyopidae: C

43.c. *Oxyopes shweta*; Oxyopidae: C
Mostly arboreal, ambush hunter preferring low herbs and shrubs.

43.d. *Oxyopes* sp. _____; Oxyopidae: C
Mostly arboreal, ambush hunter preferring low herbs and shrubs.

43.e. *Peucetia viridana*; Oxyopidae: C
Strictly arboreal, ambush hunter preferring low herbs and shrubs.

43.f. *Peucetia* sp. _____; Oxyopidae: R
Strictly arboreal, ambush hunter preferring high herbs and shrubs.

43.g. *Hamadruas* sp. _____; Oxyopidae: UC
Mostly arboreal, ambush hunter preferring low herbs and shrubs.

43.h. *Hamataliwa* sp. _____; Oxyopidae: C
Mostly arboreal, ambush hunter preferring high herbs and shrubs.

43.i. Disc web spider; *Oecobius* sp. _____; Oecobiidae: C
Small spider; mostly seen in houses where they build webs in corners near lights.

43.j. Daddy long legs; *Crossopriza* sp. _____; Pholcidae: C
Builds cobweb, most common in houses. Prefers dense thickets in natural habitat.

43.k. Daddy long legs; *Pholcus* sp. _____; Pholcidae: C
Less common than *Crossopriza* sp. Mostly seen in natural habiat than manmade.

43.l. Spitting spider; *Scytodes* sp. _____; Scytodidae: C
Partly arboreal, nocturnal in nature. Rests in a folded leaf during day. Hunts at night. Exclusively seen during monsoon months.

43.m. *Scytodes* sp. _____; Scytodidae: C
Probably an immature stage of *Scytodes* sp. discussed above.

43.n. *Scytodes* sp. _____; Scytodidae: C
Dwells in crevasses and dark corners of homes. Nocturnal in nature. Often seen inside homes unlike *43.l*.

43.o. Velvet spider; *Stegodyphus* cf *mirandus*; Eresidae: C
Builds tangled web comprising of several leaves bound together.

Plate 43

Plate 44

44.a. Crab spider; *Thomisus* sp. _____ Male (small); Thomisidae: C

Stays on or near flowers of herbs and shrubs. Ambush hunters. Males are very small, often seen piggybacking females.

44.b. cf *Ebrechtella* sp. _____; Thomisidae: C

Stays on or near flowers of herbs and shrubs. Ambush hunters. Build nest by stitching two leaves together.

44.c. cf *Diaea* sp. _____; Thomisidae: C

Mostly arboreal, stay a few feed above ground mostly on the underside of leaves.

44.d. cf *Camaricus* sp. _____; Thomisidae: C

Stays on leaves of small plants. Ambush hunters.

44.e. *Bomis* sp. _____; Thomisidae: C

Stays on leaves and stems of small plants and trees. Ambush hunters.

44.f. *Runcinia* sp. _____; Thomisidae: C

Stays on stems of small plants close to ground, just under the tip. Ambush hunters.

44.g. Ground crab spider; *Xysticus* sp. _____; Thomisidae: C

Ground dwelling, prefers leaf litter.

44.h. *Xysticus* sp. _____; Thomisidae: C

Ground dwelling, prefers leaf litter.

44.i. Ant mimicking crab spider; *Amyciaea forticeps*; Thomisidae: C

Found in close proximity to Weaver ants (*Plate 21.e*).

44.j. *Stenochilus* sp.; Stenochilidae: R

Dwells underground, seldom emerges outside. Builds thin tunnels mostly under stones.

44.k. *Clubiona* sp.; Clubionidae: C

Partly arboreal and ground dwelling, nocturnal in nature.

44.l. Dwarf hunting spider; _____; Oonopidae: C

Smallest spider of KTR; often found living under tree barks in small groups.

44.m. Net casting spider; *Deinopis* sp. _____; Deinopidae: UC

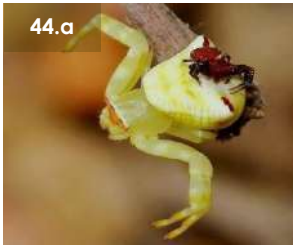
Partly arboreal, prefers dense thickets close to ground, but also found 15 feet above ground on a tree. Nocturnal in nature.

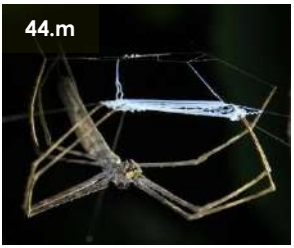
44.n, *Deinopis* sp. Cast-net closeup; Deinopidae

Image shows the typical cast-net made by cribellate silk.

44.o. *Deinopis* sp. At rest posture; Deinopidae

During daytime, the spider rests in this typical camouflaging position to avoid detection.





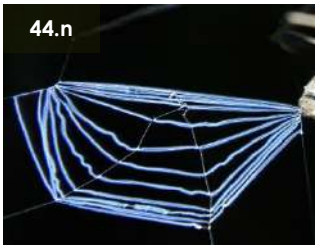


Plate 44

Plate 45

45.a. Cobweb spider; *Theridion* sp. _____; Theridiidae: C

Builds tangled webs in tree crevasses, also commonly found in corners of homes. Some species keep a dried leaf in the web as a retreat or to lay eggs.

45.b. *Steatoda* sp. _____; Theridiidae: UC

Similar in habit to *Theridion* sp., however less common. Mostly seen near old dilapidated buildings.

45.c. *Parasteatoda* sp. _____; Theridiidae: C

Small spiders, build large tangled webs on trees.

45.d. Kleptoparasitic spider; *Argyrodes* sp. _____; Theridiidae: C

Small spider mostly found in the web of other spiders, mostly orbweavers in the family Nephilidae, Araneidae, and Uloboridae.

45.e. *Argyrodes* sp. _____ Male; Theridiidae: C

45.f. Mercury spider *Argyrodes* sp. _____ Female; Theridiidae: C

45.g. *Chrysso* sp. _____; Theridiidae: UC

Small spider, often found on foliage closer to ground.

45.h. *Theridula* sp. _____ Female; Theridiidae: UC

Mostly seen during monsoon. Small spider, nocturnal in nature. Rests under a leaf during day, builds gum-foot maze webs at night to capture prey.

45.i. *Theridula* sp. Gum-foot web; Theridiidae

Typical gum-foot web of Theridula sp. can span upto 1 feet or more in length. The gum-foot web is made up of highly sticky silk. Insects such as gnats, fruit flies, and craneflies are caught in this web.

45.j. *Theridula* sp. Use of non-sticky silk for maneuvering through web; Theridiidae

The spider itself uses a non-sticky silk to maneuver around the gum-foot web to ensnare trapped insects.

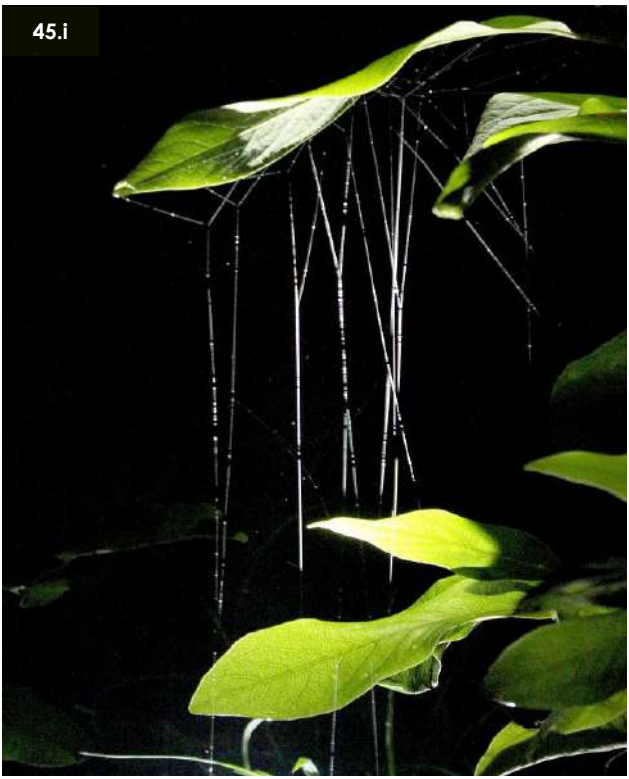


Plate 45

Plate 46

46.a. Hackled orbweaver; *Uloborus* sp. _____; Uloboridae: C

Small spiders, build small, horizontal orbwebs mostly in crevasses and caves. One species often found in verandah of homes where it builds small sheet of web adjoining the roof.

46.b. *Opadometa fastigata*; Tetragnathidae: C

Mostly seen during monsoon only; build horizontal orbwebs in thickets.

46.c. Orchard spider; *Leucauge decorata*; Tetragnathidae: C

Same in habit and share the same habitat as *O. fastigata*.

46.d. Long jawed orb weaver; *Tetragnatha* sp. _____; Tetragnathidae: C

Most commonly observed near damp places such as gutters, also common in natural water bodis such as ponds, streams and lakes. Build horizontal orbwebs. Retreat to nearest branch when disturbed and assume a flat, stick-like posture.

46.e. *Tetragnatha* sp. _____; Tetragnathidae: C

46.f. *Tetragnatha* sp. _____; Tetragnathidae: C

46.g. *Tetragnatha* sp. _____ Male showing palps; Tetragnathidae: C

This genus shows typically enlarged fangs. This image also portrays the palps present only in males which are used to deposit sperms.

46.h. Giant wood spider; *Nephila pilipes* Female; Nephilidae: C

Build largest webs in KTR. Most common during post-monsoon and early winter months. Build webs as high as 10 to15 meters from ground.

46.i. *Nephila pilipes* Male; Nephilidae: C

Males are noticeably smaller than females.

46.j. *Nephila pilipes* Immature; Nephilidae: C

Immature spiderlings are commonly seen during early monsoon months. Are preyed upon by Mud dauber wasp (*Plate 26.j*) during monsoon as a food source for its grubs.

46.k. Black wood spider; *Nephila kuhlii*; Nephilidae: C

Share the same habit and habitat as *N. pilipes*, however *N. kuhlii* is more commonly observed near waterbodies and build smaller webs.

46.l. Ornate tree trunk spider; *Herennia multipunctata* Female; Nephilidae: R

Tree-bark dwelling spider, females makes ladder-like modified orbwebs on tree trunks. Males are noticeably smaller than females and orange in colour.

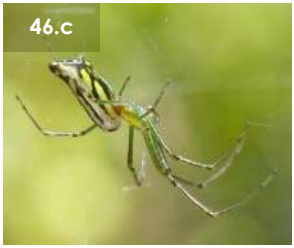


Plate 46

Plate 47

47.a. Signature spider; *Argiope pulchella* Female; Araneidae: C

Builds orbwebs, commonly observed during monsoon.

47.b. *Argiope pulchella* Immature female; Araneidae

Immature spiders build smaller orbwebs often close to the surface of walls or trees.

47.c. *Argiope pulchella* Male; Araneidae

Males are often found close to females.

47.d. *Argiope aemula* Female; Araneidae: C

Shares the same habit and habitat as *A. pulchella*, however is less common.

47.e. Tent spider; *Cyrtophora* sp. _____; Araneidae: UC

A larger species, build large, dome-shaped web about 5 feet above ground on trees.

47.f. *Cyrtophora* sp. _____; Araneidae: C

A smaller, more common species; builds dome-shaped webs. Often found in large clusters near light sources.

47.g. *Araneus* sp. _____; Araneidae: C

Most common during monsoon. Build small, slightly horizontal orbwebs near light souces at night. Rest in crevasses during day.

47.h. *Araneus/Neoscona* sp. _____ Male; Araneidae: C

Males of some species do not build orbwebs, instead rest on leaf surfaces.

47.i. *Neoscona* sp. _____; Araneidae: C

Build medium-sized orbwebs, commonly observed in gardens as well.

47.j. *Larinia* sp. _____; Araneidae: C

Build large orbwebs, share the same habit and habitat as other orbweavers.

47.k. *Poltys* sp. _____; Araneidae: UC

Cryptic in nature; strictly nocturnal, build large orbwebs at night and remain hidden on tree barks and stems during day. Can live upto more than a year.

47.l. *Poltys* sp. _____; Araneidae: UC

A smaller species sharing the same habit as the one discussed above.

47.m. *Eriovixia* sp. _____; Araneidae: C

Small orbweaver, but builds large orbwebs at night.

47.n. *Cyclosa* sp. _____; Araneidae: C

Very small orbweavers, build small orbwebs in the undergrowth.

47.o. *Cyclosa* sp. Typical debris collection in web; Araneidae

Cyclosa sp. is known to decorate webs with debris such as seeds, stones, and parts of captured prey. The spider rest roughly in the middle or at the edge of this collection to avoid detection.

Plate 47

3.24 Non-spider arachnids

The non-spider arachnids of KTR are represented by Order Scorpiones (scorpions), Opiliones (harvestman), Pseudoscorpionida (pseudoscorpions), and subclass Acari (ticks and mites). Studies on these orders are rather basal in this region, with only scorpions receiving the most attention; 19 species of scorpions are recorded from Madhya Pradesh (Bastawade, Jadhav and Sharma, n.a.). Studies on pseudoscorpions, a small but important predatory arachnid, are mostly from southern India, with few scattered studies done on harvestman. Ticks have received considerable attention for their role in spreading diseases such as Kyasanur Forest Disease, and in causing allergies when bitten; and most mites are considered parasites and pests of a variety of animals including insects, spiders, and plants. One the the most noticeable of mites is the predatory Red Velvet Mite, *Trombidium grandissimum*, which appears on the ground during early monsoon showers. KTR is home to at least 3-4 species of scorpions, 2 species of pseudoscorpions, and there are several species of harvestman, ticks, and mites.

Plate 48

48.a. *Buthoscorpio* sp.; Buthidae; Scorpiones: UC
Mostly live under rocks or heavy leaf litter.

48.b. *Lychas* sp.; Buthidae; Scopiones: C
Most common scorpion of KTR; <2cm in size; Lives under leaf litter, rocks, tree bark.

48.c. *Heterometrus* sp.; Scorpionidae; Scorpiones: C
Largest scorpion of KTR; encountered occasionally during monsoon. Make horizontal burrows especially on sloping open-face earth, or under large rocks.

48.d. Pseudoscorpion; _____; Pseudoscorpionida: R
Very small (<1cm), encountered on barks of trees.

48.e. Pseudocsocpion; _____; Pseudoscorpionida: R
Very small (<1cm), encountered on barks of trees such as Saja.

48.f. Harvestman; _____; Opiliones: C
Spider-like, but cephalothorax and abdomen is fused unlike in spiders. Make large congregations near shady places during summer.

48.g. Forest tick; _____; Acari: C
Commonly encountered on forest tracts. Small in size (<1cm).

48.h. Red Velvet Mite; *Trombidium grandissimum*; Trombidiidae; Trombidiformes: C
Small, brilliant red predatory mites found commonly on the forest floor. Adults lead a largely underground life and act as important predators of their microhabitats.

48.i. Velvet Mite; _____; Trombidiidae; Trombidiformes: C

Plate 48

4. Spider density of KTR

For every two insects in KTR, there is one spider lurking in the undergrowth. From an ecological perspective, this statement signifies two aspects: a healthy relationship between predator and prey, since spiders are voracious but niche-specific obligate carnivorous invertebrates, and occupy vitually every niche in a terrestrial ecosystem dominated by insects (Turnbull 1973), and interspecific competition within spiders. Spiders of KTR occupy all the niches occupuied by their prey, including freshwater ecosystems; and they have chosen their niches along the gradient of KTR's forest and grassland ecosystems to exploit this abundant prey population: from under the forest floor and leaf litter to wetlands, to tree barks, leaves, and up high in the tree canopies. This variety of spider occupancy therefore signifies a rather strong and robust equilibrium of the ecosystem.

Our curiousity to know which is the most common insect of KTR's natural ecosystems also extended to know which is the most common spider – and we found an unlikely candidate to be the most common: the Lynx spider (*Oxyopes* cf *javanus*; Oxyopidae), followed by Wolf spider (*Lycosa* sp.; Lycosidae), and Jumping spider (*Stenaelurilus* sp.; Salticidae), followed by members of Araneidae (True orbweavers), Thomisidae (Crab spiders), and Theridiidae (Comb footed spiders). The reason for this particular density was because of the hot and dry summer season, which restricted the movement of insects and thereby of spiders.

Density studies for spiders were undertaken alongside the study for insects using quadrat method (*see Sec 5.1*) in four distinct vegetation types (*see Sec. 5.2*); Sal dominant forests (SD), mixed deciduous forests (MD), bamboo dominant forests (BD), and grasslands (GL). SD recorded the highest number of families along with the highest density of spiders (54%), followed by MD (34%), BD (10%), and GL (2%). Family-level diversity was relatively higher in SD and MD, and low in BD and GL probably because of the lack of shade and high temperatures during summer months (*Figure 12*).

It was also observed that forest-type plays a significant role in determining the ecology of spiders. Although the three prominent families, viz. Oxyopidae, Lycosidae, and Salticidae, were present in all ecosystems, they showed significantly different densities in either of the ecosystems. This assemblage of spider communities shows a direct correlation as well as a greater reliance on the assemblages of insect communities which also showed similar diversity and density trends (*see Sec. 1 Chap. 14*).

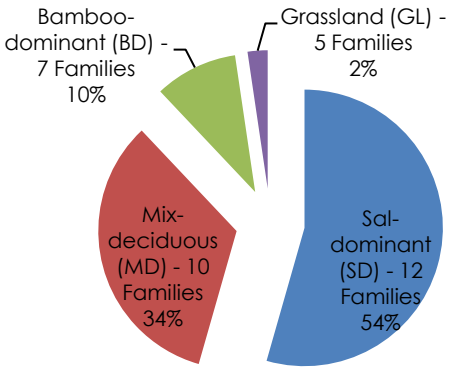


Figure 11. Ecosystem-wise density and diversity of spider families of KTR

The overall dominant families according to the number of individuals recorded were Oxyopidae (31.3%), Lycosidae (30%), and Salticidae (27%). Other families constituted 11.7% of the total. As per the percent relative abundance calculated for each ecosystem (*Figure 13*), Oxyopidae was found to be most dominant in SD and GL, Salticidae in MD, and Lycosidae in BD.

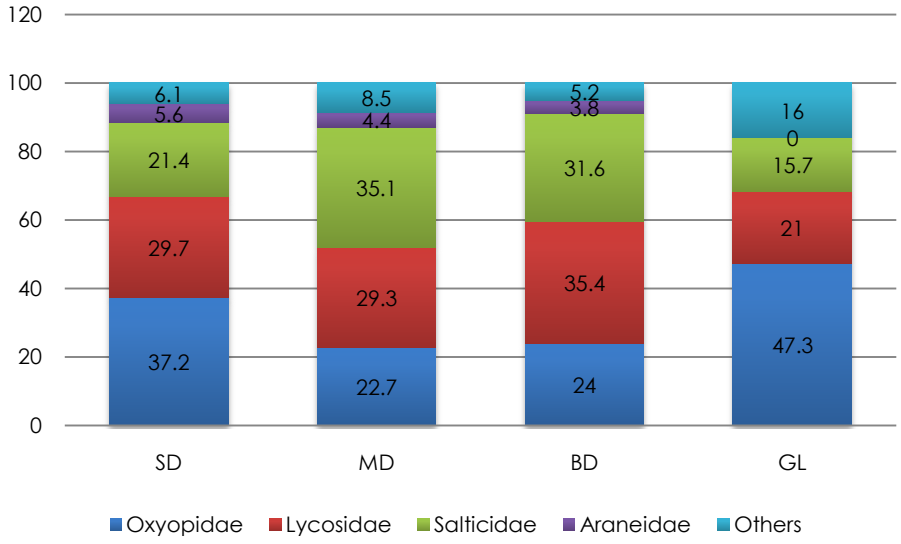


Figure 12. Ecosystem-wise percent relative abundance of four major spider families of KTR

The higher diversity and density of spiders in SD forests can be attributed to Sal (*Shorea robusta*) trees which remain green almost throughout summer, thus provide shade, retain moisture, and a dense-to-moderate groundcover predominated by Sal leaf litter. MD forests were represented by deciduous trees. In such forests temperatures are high and moisture low during summer, this is perhaps the reason for low diversity in comparison to SD. BD forests are dry for the most part of summer and subject to high temperature, yet provide considerable amount of shade in comparison to GL which is dry and subject to intense temperatures during summer.

An ecological guild-based approach revealed that wandering spiders are most common in KTR (48%), followed by orbweb builders (18%), stationary ambush hunters (14%), and cobweb builders (6%). The forest zone preference of spiders showed trees and its various parts, such as bark, leaves, and stems, to be the most preferred niche with 66% of the spider diversity using it to catch prey, build nest, or live as a retreat. 29% of the spiders were ground-dwelling, and 5% relied on natural as well as man-made niches such as walls and storage places.

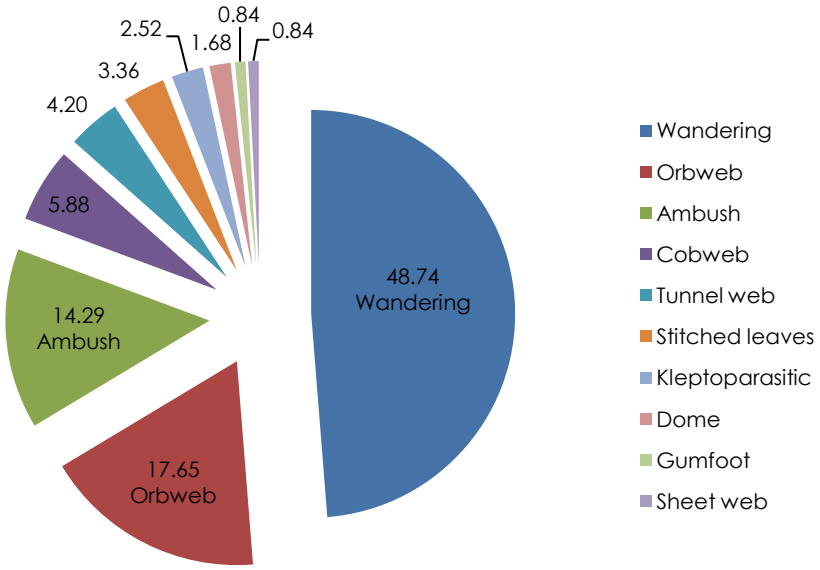


Figure 13. Ecological guild of spiders of KTR

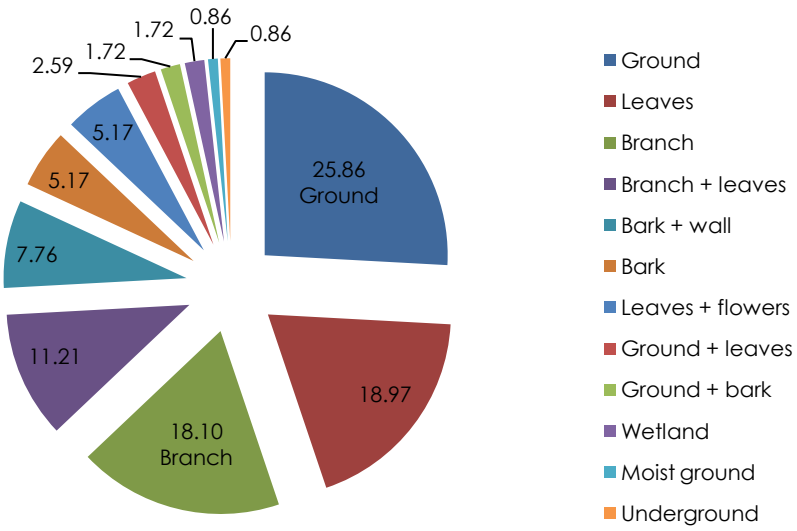


Figure 14. Specific niche preferences amongst spiders of KTR

The most abundant members of Oxyopidae, Lycosidae, and Salticidae occupied a similar niche of forest undergrowth, i.e. forest floor; hence their role in the undergrowth as strictly predatory invertebrates is noteworthy. In comparison to the presence of other predatory invertebrates which were surveyed alongside spiders, such as Praying Mantis (Insecta: Mantodea), Assassin Bug (Insecta: Hemiptera), Dragonflies and Damselflies (Insecta: Odonata), and Ants (Insecta: Hymenoptera), ants, specifically Weaver Ants (*Oecophylla smargdina*), were found to be most abundant predatory insects in the undergrowth, however it did not seem to affect the density and diversity of spiders sharing the same niche.

Spiders, although ubiquitous in nature and active hunters of an array of life-forms, show a distinct preference of certain ecosystems at family-level, and distinct niches at species-level. In addition to biotic factors such as availability of prey-base as well as competition from other predatory invertebrates, ecosystem-specific preference is mainly attributed to abiotic factors, including availability of shade, temperature, humidity, and rainfall (Lubin, 1978; Churchill, 1998).

The study which was conducted during summer months reveals a distinct picture of spider ecology as compared to monsoon or winter months when spider diversity is higher and overlapping owing to the availability of favourable biotic and abiotic factors discussed above.

Further studies focusing on the habitat-use and niche-preference, inter- and intra-specific competition for food and space, and role of abiotic factors such as temperature and humidity, along with taxonomic research, are required to understand the ecological importance of spiders. This study therefore merely serves as a prelude for future studies to help determine the diversity and the role of spiders in the ecosystem functioning of KTR.

Section III
Role of
INSECTS & SPIDERS

1. Food-web of KTR

Insects and spiders are often missing when portraying a food-web of an ecosystem, although they play nearly the same role as plants in providing nutrition to higher organisms, and are probably the only ones besides birds to be of invaluable services to plants for pollination. This section discusses several aspects of the role played by insects and spiders in KTR, along with some of their traditional uses and threats to their diversity in KTR.

1.1 Key ecosystem services

Ecosystem services are broadly classified into provisioning, regulating, cultural, and supporting services (TEEB 2010). Provisioning services includes direct benefits to humans in terms of provision of food, raw materials, water, and medicinal resources. Regulating services include climate regulation, pollination, biological control, carbon sequestration, moderation of extreme events, prevention of erosion and maintenance of soil fertility, and waste water treatment. Cultural services include recreation, tourism, aesthetics and spiritual experience offered by nature; and supporting services include provision of habitats for species, and maintenance of genetic diversity.

Insects and spiders form a virtual connecting link between all these services by directly contributing to a service, such as pollination and biological control, or are utilized as raw materials for various products, including honey, silk, and lac, or are used as indicators for measuring the health of an ecosystem, as well as in gardens for their aesthetic values. Insects are also used widely in the field of medicine, genetics, and bioengineering. This virtue, which is seldom possessed by any single group of organisms, makes them not only diverse, but also resilient in their survival. This resiliency is further imparted to an ecosystem they are a part of, and wherein they are providing their invaluable ecosystem services.

Some of the key ecosystem services of insects and spiders are discussed below, and conservative estimates of their role in KTR's ecosystems are deduced based on their habit, lifecycle, and ecology.

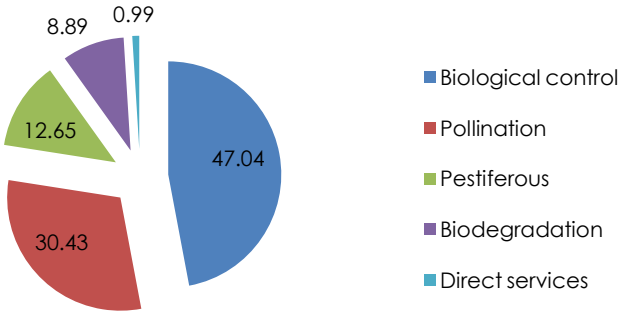


Figure 15. Key roles of insects of KTR based on their ecosystem services

1.1.1 Pollination

Pollination is the most recognised of services of insects, with Lousey and Vaughn (2006) estimating $3.07 billion worth of services in USA for pollination alone. They pollinate about 60–70% of all plant species, and about 35% of global crop-based food production (Schowalter 2011; Losey and Vaughn 2006). Understanding pollination success of insects is difficult, hence only a rough estimate of over 30% of all insects aiding in pollination is deduced from this study based on their feeding behaviour. This estimate is an addition of two classes of pollination: uncertain pollination, which is attributed to insects that feed on flowers but do not necessarily pollinate (such as butterflies and moths), and those that do (such as bees and wasps).

1.1.2 Biological control (predatory and parasitic)

Losey and Vaughn (2006) estimate $4.49 billion worth of services by insects in USA for pest control of native herbivores. Several insects and almost all spiders act as biological pest controlling agents either through direct predation, such as by ladybird beetles and spiders, or through parasitism, such as by certain wasps. A rough estimate based on the natural history of insects and spiders recorded in the present study shows over 47% of insects and spiders engaged in some sort of biological control in forest and agro-ecosystems of KTR. Use of such insects in agro-ecosystems for pest control needs to be explored for efficient and less chemical-intensive farming practices.

1.1.3 Biodegradation and decomposition

Losey and Vaughn (2006) estimate $0.38 billion worth of services by insects in USA for dung burial, a crucial ecosystem services aiding in dispersal of nutrients in the ground. Insects play a critical role in biodegradation of human-generated waste, and decomposition of natural organic matter such as carrion and deadwood. Entry of fungus, an important plant decomposer, into the hard and tough organic material such as wood is enabled by insect burrows, and flies (Order Diptera) play a crucial role in flesh opening of carrion. Life history of insects reflects their role in this ecosystem service; based on this, an estimate of 9% of insects recorded during the study undertake this important ecosystem service.

1.1.4 Direct ecosystem services to man

Only 0.99% of insect diversity is being used directly by local communities for their direct benefits. The major insects that provide such services are *Apis dorsata*, *A. cerana*, and *Listorigona* sp. (*plate 26.a–26.d*) that provide honey which is extracted traditionally by tribal communities. Lac production (*plate 14.o*) is also undertaken by certain Eco-development Committees, along with government-ventures of silviculture common in the periphery of KTR.

1.1.5 Pestiferous insects

Pestiferous species are those that cause damage to human property, including standing crops, stored grains, wood stock, human health, livestock health, or are a nuisance. About 13% of insects recorded under the present study are pestiferous in nature, causing a considerable amount of damage to human property.

1.2 Food source of birds

Of the 270 species of birds recorded in KTR (D'cunha 1998; D'cunha *pers. comm*.), at least a hundred species eat insects and spiders at some stage in their lifetime, either by feeding them to the young ones or eating them as adults. The breeding season of some birds and the timing of the fledgling leaving nests coincide with the sudden outburst of insects such as alate termites and grasshoppers during the pre-monsoon showers. This large number is an evidence of the importance of insects and spiders in the food-web of KTR.

1.3 Food source of mammals

Of the 59 species of mammals recorded in KTR (Harshey and Chandra 2001), at least 25 species eat insects and spiders as a part of their diet, of which 18 are true insectivores and include large mammals such as Sloth Bear and as small as the shrew. Of the 15 species of bats recorded in KTR, 12 are insectivorous in nature. About 7 species are known to occasionally eat insects as a supplement to their diet, and include species such as mongoose and rodents.

1.4 Some traditional uses

Insects play a certain role in local traditions in KTR. Although the noncommercial use of insects in various forms – either as a source of food or in medicines – is now a dying science, some forms of its uses still remain. I came across only two occasions where insects or insect-derrived products were used in tradition and medicine among Baiga communities in KTR. The mud of nest created by potter wasps (*plate 24.g–24.i*), locally called *ghangedi mitti*, is dissolved in warm water and consumed to treat symptoms of nausea and dizziness. This medicinal use of the potter wasp mud could be attributed to the typical loamy soil which is further refined by the wasps by filtering it using their mouth. This mud acts as an adsorbent, probably on the same lines as charcoal.

The termite mounds of *Odontotermes* sp. (*plate 32.j and 32.m*) is locally called '*bhimora*'. The mound soil is traditionally being used in marriage ceremonies by Baiga communities for many generations. The groom and bride along with their family members at their respective homes are supposed to dig a part of the mound by themselves and hand it over to their family members, who then carry it back to the house to build a traditional structure called '*mangru*'. This soil-structure is roughly dome-shaped, and is erected in the verandah at both, the groom's and the bride's home, until the marriage ceremony is over.

Oudhia (2005) recorded traditional medicinal uses of over 500 species of insects and mites by tribal communities in Chhattisgarh; however, although the culture and traditions are similar, very few insects seem to be used in traditional medicine in KTR. A case in point is that of Red Velvet Mite (*plate 48.h*) which is used for preparing medicines of about 10 diseases in Chhattisgarh, however here it is considered as holy by Baiga communities, and is not killed. Locally it is also called "*dev keeda*". With access to modern medicine, traditional knowledge of use of insects appears to be fast fading, and is important to be preserved in enthnoemtomological literature before this traditional science dies out.

1.5 Threats to, and threats from, insects and spiders

Insects and spiders face threats similar to the ones faced by vertebrates. While none of them are on the endangered list, anthropogenic pressures act in similar ways on their diversity, density, and community assemblages. Several beneficial insects of cities have already vanished, such as Ensign Wasp (*plate 25.m*) and are now only seen in Protected Areas such as KTR. Perhaps the biggest threat to this group of invertebrates is the great lacuna of knowledge about their existence. Some of the common threats to insects and spiders of KTR is discussed herein.

Habitat degradation and fragmentation in the form of construction, agricultural land expansion, grazing, and forest fire affect insect and spider assemblages significantly. Since they play a crucial role in maintaining the microhabitat ecology of forests, these disturbances delay basic processes such as degradation and decomposition, pest control, as well as weed control in the understorey, making the land less productive. Poor density of insects lowers the production of frass (insect feces), a potential natural fertilizer beneficial for the soil, although no studies in the context of understanding impact of frass in nutrient recycling have been undertaken. This concept is explained by Rinker and Lowman (2004).

An imbalance in insect and spider diversity can also trigger population explosion of serious pests such as locusts and wood boring insects, which are kept under check by predatory and parasitic animals. Studies on population dynamics of predators and parasitoids of the Sal woodborer beetle (*plate 12.c; chap. 4.2*), once identified, can serve as answers to periodic infestations on Sal trees.

Au contraire, residents of KTR and their livestock and crops are also threatened by insects in some ways. The most serious of the threats is of malaria, spread by *Anopheles* sp. mosquito. Housefly, Fleshfly, and Blue bottle fly (*plate 18.a–18.c*) get attracted to open wounds on livestock and lay eggs, causing myiasis. Insects infest a number of crops, causing economic losses. Although they do not cause serious harm, stings from ants, bees, and wasps (*plate 21.a–26.o*), and scorpions (*plate 48.a–48.c*), and bites of spiders such as Huntsman spider (*plate 42.c–42.g*) may be clinically significant by showing an allergic reaction.

It is however worthy of note that insects and spiders seldom bite or sting unless in self-defense. Their crucial role in the ecosystem is well established and recognised; to quote E. O. Wilson, "If all humankind were to disappear tomorrow, it is unlikely that a single insect species would go extinct, except three forms of human body and head lice. If insects were to vanish, the terrestrial environment would soon collapse into chaos."

Section IV
DISCUSSION

1. Discussion and recommendations

The role of insects (and spiders) as herbivores, pollinators, seed dispersers or prey (and predators) is important to be considered as a part of conservation and restoration planning (Schowalter 2001). In view of this, some recommendations in the form of discussion are made below.

1.1 Scientific monitoring

A thorough, multidisciplinary approach is important to assess the actual diversity and density of KTR's invertebrate fauna by combining taxonomic and ecological studies. KTR can play a 'role model ecosystem' for studies on the impact and the resiliency of insects, spiders, as well as higher animals and plants with respect to climate change and the predicted global warming. Its role as a natural carbon sink should not only restrict to flora, but extend to these invertebrates which play a crucial role in nutriend recycling, and are a significant part of KTR's biomass.

1.2 Biological control

I predict KTR's diversity to be highly resilient from the attacks of serious pests such as Sal borer beetle, defoliator moths, and locusts – partly because it is diverse in predators and parasitoids which control pest populations in some ways. Studies exploring and identifying such beneficial biological pest controlling agents present within the reserve's indigenous pool and their wise use in combating pest outbreaks not only in forest ecosystem management but also in agro-ecosystems that surround the park will be crucial in maintaining the ecological equilibrium where pests are controlled naturally.

1.3 Ecosystem services inventory

The ecosystem services of insects and spiders are rather difficult to assess, although studies have been undertaken which predict their true value in a measurable unit. Losey and Vaughan (2006) estimated the ecological services provided by insects in the USA to be at least $57 billion, and Nyffeler (2000) estimated, based on literature, that spiders kill to the order of 200 kg per hectare per year, a significantly large rate of predation which, according to the author, may indeed exert high predation pressure under favourable conditions. KTR's economic valuation was placed at Rs. 16.5 billion annually for flow benefits, and Rs. 12.41 billion per year, Rs 558 million per year, Rs 546 million per year, Rs 384

million per year, Rs 319 million per year, and Rs 291 million per year based on its ecosystem services of gene-pool protection, provisioning of water to downstream regions, provisioning of fodder in buffer areas, recreation value, and provision of habitat and refugia for wildlife, and sequestration of carbon respectively (Verma et al 2015). The study also estimates economic value of pollination in KTR at Rs. 245.34 million per year and that of biological control at Rs. 89.96 million per year.

Studies pertaining to insect or in general animal-pollinated and dispersed plants can help significantly in habitat restoration programmes as well as help ascertain a value based on their services to the adjoining agro-ecosystems.

1.4 Insect-based habitat restoration

Current afforestation and habitat restoration programmes focus more on the flora than the associated components of an ecosystem – animals. The belief that trees will eventually attract animals – from insects to birds and mammals, is usually a critically slow process, requiring a considerable amount of time (mostly years) to happen. This also leaves a gap for a number of unforeseen incidences to happen, such as excessive cattle grazing. An alternate, intensive process of undertaking habitat restoration is introduction of insect-attracting plants in a step-wise manner; it is proposed here in short.

After the initial stage of weed removal, such as Lantana and Parthenium, plantation of locally common flowering herbs and shrubs that attracts fauna, and especially insects and spiders, should be undertaken to speed up the process of habitat restoration. Noting the trend in the increase in the density of these invertebrates may prove as an indicator of increasing biomass of the area. Plantation of tree species found in that particular ecosystem should be undertaken with a preference to trees which usually attract fauna, in case of KTR, trees such as Palash, Harra, Bahera, Tendu, etc attract a number of bees, wasps, butterflies, beetles, flies, and birds. It is crucial to maintain a no-go zone in such sites for lopping and grazing, which can be detrimental for the restoration process. A study shows that flower density is more important to a site for insect diversity than the presence of specific habitats (Scriven, Sweet, and Port 2013). This can be applied in insect-based habitat restoration programmes.

In view of this, it is vital to empower local nurseries to grow more species of locally common flowering herbs, shrubs, and locally common trees. While exploring nurseries for their diversity of insects and spiders, only about five to seven major species of local trees were recorded – since forest areas comprise of at least

more than 10 different species of trees, this small mosaic of nursery sapling will be unable to attract insect diversity and increase chances of pest attacks.

1.5 Butterfly garden in buffer zone

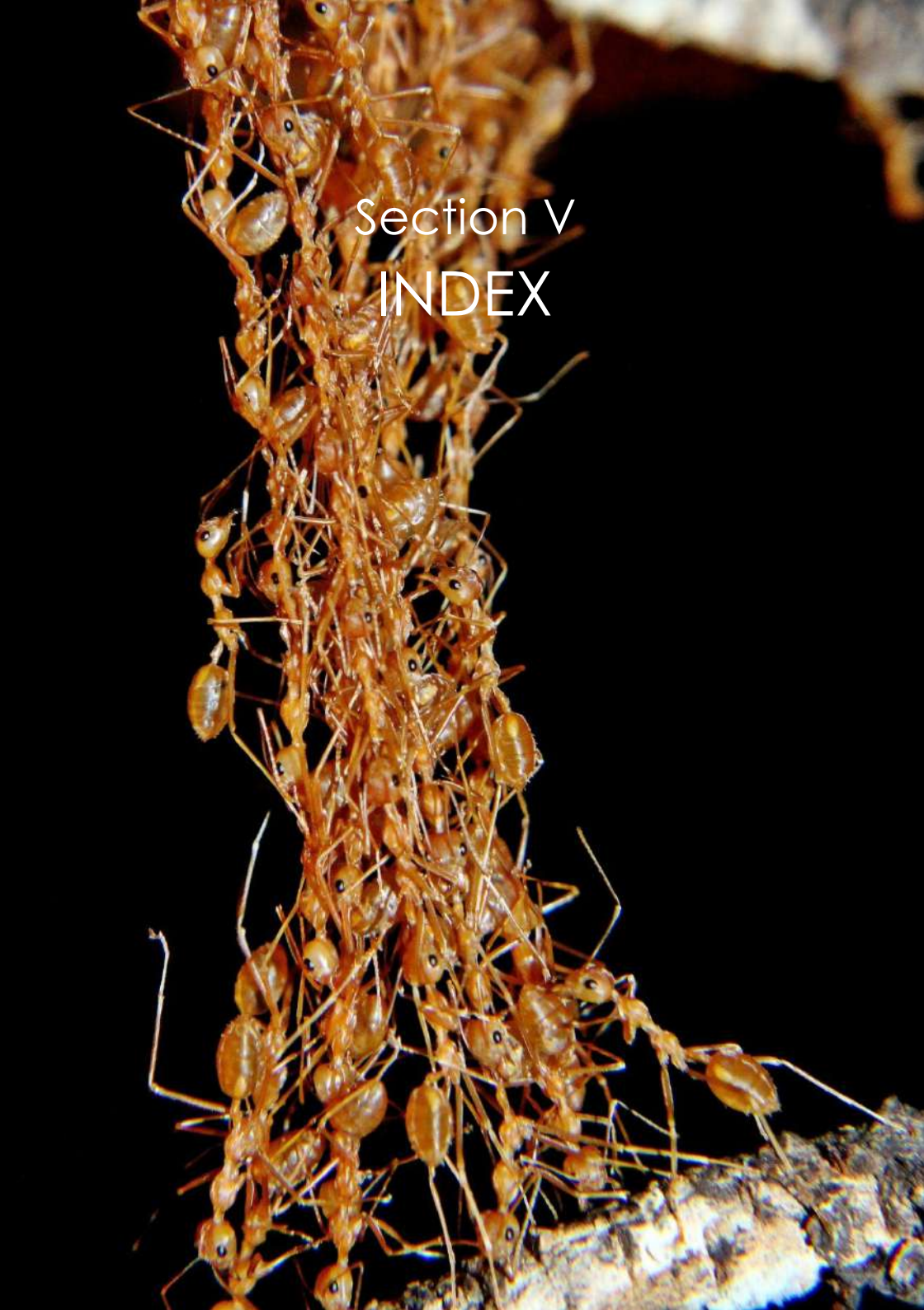
Butterfly gardens are a common concept, and attract a number of tourists to watch and learn about insects, and specifically butterflies. Such gardens serve as an important source of inspiration and develop an understanding about insects (and by extension spiders). Butterfly gardens can serve as an extension of the insect-based habitat restoration progammes in the buffer zone of KTR, which can be open for tourists. A careful inventory of seasonal flora and insect fauna however needs to be undertaken in order to maintain a year-long, seasonal garden. A list of 25 species of herbs and shrubs and 10 species of trees present in KTR that attract insects and other animals is provided in *Section V, Chap. 3*.

1.6 Increasing awareness

Awareness is critical to apprise young minds and season them towards a harmonious coexistence between man and nature. Insects and spiders seldom form a part of academic curriculum from where the major source of knowledge about the natural world is imparted. Although insect lifecycle, their basic diversity, and their role in spread of diseases is a critical part of introducing insects and spiders to students, outdoor activities, where they can see the processes in action, such as metamorphosis, are critical for an early development of fondness towards these least understood, but important, organisms.

Since KTR is visited by a number of tourists every year (more than 1 lakh visitors per year), dissemination of information pertaining to insects and spiders that call it home can be undertaken using posters, booklets, as well as conscise fieldguides on the lines of birds and mammals. Several fieldguides on butterflies, dragonflies and damselflies, ants, as well as spiders are already available in the Indian context – provisioning of these books in library or through souvenir shops can serve as an entry point into the world of insects. Furthermore, sensitizing the young minds through interactive workshops, nature walks, and pictures can pique their interest in this subject.

These suggestions are restricted not only to insects and spiders, but can be extended to all the wide range of wildlife that calls KTR its home, including grasses, mollusks, fishes, and other lesser known forms of life.



Section V
INDEX

This section comprises of the list of insects and spiders of KTR along with their plate numbers, and a list of 35 species of locally occurring flora which can be used for plantations, insect-based habitat restoration, and for developing a butterfly garden. The list of plants is prepared by referencing Pandey and Namdeo (2009), Krishen (2013), and Kehimkar (2009). Host specific list of flora can be referred from KFRI (n.a.). A complete bibliography of the sources cited is given at the end of this section.

1. Index of insects of KTR

Plate	Family	Common Name	Scientific name
	LEPIDOPTERA		
1.a	Papilionidae	Blue Mormon	*Papilio polymnestor*
1.b		Common Mormon	*Papilio polytes*
1.c		Common Rose	*Pachliopta aristolochiae*
1.d		Crimson Rose	*Pachliopta hector*
1.e		Lime Butterfly	*Papilio demoleus demoleus*
1.f		Spot Swordtail	*Graphium nomius nomius*
1.g		Tailed Jay	*Graphium agammenon*
1.h	Pieridae	Common Jezebel	*Delias eucharis*
1.i		Common Grass Yellow	*Terias hecabe simulata*
1.j		Common Emigrant	*Catopsilia pomona*
1.k			*C. pomona* form *catilla*
1.l		Mottled Emigrant	*Catopsilia pyranthe pyranthe*
1.m		Spotless Grass Yellow	*Eurema laeta*
1.n	Nymphalidae	Plain Tiger	*Danaus chrisippus*
1.o		Striped Tiger	*Danaus genutia*
2.a		Common Wanderer	*Pareronia valeria hippie*
2.b		Pioneer	*Belonois aurota aurota*
2.c		Psyche	*Leptosia nina nina*
2.d		Blue Tiger	*Tirumala limniace leopardus*
2.e		Common Leopard	*Phalanta phalanta*
2.f		Painted Lady	*Cynthia cardui*
2.g		Common Indian Crow	*Euploea core core*
2.h		Great Eggfly	*Hypolimnas bolina*
2.i		Danaid Eggfly	*Hypolimnas misippus*
2.j		Common Evening Brown	*Melanitis leda ismene*
2.k		Long brand Bushbrown	*Mycalesis visala visala*
2.l		Long brand Bushbrown	*M. visala visala* Dry Season Form
2.m		Common Fourring	*Ypthima asterope*
2.n		Common Tree Brown	*Lethe rohira*
2.o		Bamboo Tree Brown	*Lethe europa europa*
3.a		Chocolate Pansy	*Precis iphita pluviatilis*
3.b		Grey Pansy	*Junonia atlites*
3.c		Peacock Pansy	*Junonia almana almana*
3.d		Yellow Pansy	*Junonia hierta hierta*

3.e		Blue Pansy	*Junonia orithya swinhoei*
3.f		Lemon Pansy	*Junonia lemonias vaisya*
3.g		Common Sailer	*Neptis hylas astola*
3.h		Short Banded Sailer	*Phaedyma collumella*
3.i		Staff Seargent	*Athyma selenophora*
3.j		Commander	*Moduza procris procris*
3.k		Baronet	*Symphaedra nais*
3.l		Common Baron	*Euthalia aconthea garuda*
3.m		Gaudy Baron	*Euthalia lubentina*
3.n		Tawny Rajah	*Charaxes bernardus*
3.o		Black Rajah	*Charaxes solon*
4.a		Common Palmfly	*Common Palmfly*
4.b		Orange Oakleaf	*Kallima inachus huegeli*
4.c		Tawny Coster	*Acraea terpsicore*
4.d		Suffused Double Banded Judy	*Abisara bifasciata*
4.e	Lycaenidae	Angled Sunbeam	*Curetis acuta*
4.f		Angled Pierrot	*Caleta decidia*
4.g		Common Pierrot	*Castalius rosimon rosimon*
4.h		Red Pierrot	*Talicada nyseus*
4.i		Zebra Blue	*Leptotes plinius*
4.j		Dark Cerulean	*Jamides bochus bochus*
4.k		Common Cerulean	*Hamides celeno aelianus*
4.l		Forget-me-not	*Catochrysops strabo strabo*
4.m		Gram Blue	*Euchrysops cnejus*
4.n		Plains Cupid	*Chilades pandava*
4.o		Indian Cupid	*Everes lacturnus*
5.a		Lesser Grass Blue	*Zizina otis sangra*
5.b		Tiny Grass Blue	*Zizula hylax*
5.c		Plain Hedge Blue	*Celastrina lavendularis puspa*
5.d		Common Silverline	*Spindasis vulcanus vulcanus*
5.e		Large Oakblue	*Arhopala amantes*
5.f		Leaf Blue	*Amblypodia anita*
5.g		Common Guava Blue	*Virachola isocrates*
5.h		Indian Red Flash	*Rapala iarbus*
5.i		Apefly	*Spalgis epius*
5.j		Pea Blue	*Lampides boeticus*
5.k	Hesperiidae	Brown Awl	*Badamia exclamationis*
5.l		Malabar Flat	*Celaenorrhinus ambareesa*
5.m		Tricolour Pied Flat	*Coladenia indrani*
5.n		Common Small Flat	*Sarangesa dasahara*
5.o		Dark Palm Dart	*Telicota ancilla bambusae*
6.a		Straight Swift	*Parnara naso bada*
6.b		Rice Swift	*Borbo cinnara*
6.c		Common Grass Dart	*Taractrocera maevius*
6.d		Indian Skipper	*Spialia galba*
6.e		Indian Palm Bob	*Suastus gremius*
6.f		Common Banded Awl	*Hasora chromus*
7.a	Sphingidae	Hawkmoth	*Acherontia styx*
7.b			*Clanis phalaris*

7.c			*Theretra alecto*
7.d			*Daphnis nerii*
7.e			*D. nerii* Caterpillar
7.f			*Argius convolvuli*
7.g			*Ambulyx sp.*
7.h			*Agnosia microta*
7.i			*Cephonodes hylas*
7.j	Geometridae		*Ascotis imparata*
7.k			*Dysphania sp.*
7.l			*Synchlora sp.*
7.m			*Spoladea recurvalis*
7.n			*Antigastra catalaunalis*
7.o			*Nymphicula blandialis*
8.a	Erebidae		*Utethesia pulchella*
8.b			*Spirama retorta*
8.c			*S. retorta* Dark Morph
8.d	Lymantriinae		*Lymantria sp.*
8.e			*Lymantria mathura*
8.f			*L. mathora* Caterpillar
8.g			*Perina nuda*
8.h	Arctiinae		*Amata sp.*
8.i			*Rajendra vittata*
8.j	Notodontidae		*Paracerura priapus*
8.k	Zygaenidae		*Trypanophora sp.*
8.l			*Trypanophora sp.* Caterpillar
8.m	Limacodidae		*Belippa sp.*
8.n			*Parasa sp.*
8.o	Pterophoridae	Plume moth	Unidentified
9.a	Pyralidae		*Endotricha sp.?*
9.b	Noctuidae		*Polytela gloriosae*
9.c			*Agaristinae*
9.d			*Chalciope mygdon*
9.e	Uraniidae		*Micronia aculeata*
9.f	Cossidae		*Xyleutes persona*
9.g	Eupeterotidae	Wooly Bear Caterpillar	*Unidentified*
9.h			*Eupterote undata*
9.i	Saturniidae	Luna Moth	*Attacas selene*
9.j	Psychidae	Bagworm	*Unidentified Caterpillar*
9.k			Cucoon
9.l			Pupa
9.m	Crambidae		*Maruca vitrata*
	COLEOPTERA		
10.a	Coccinellidae	Ladybird beetle	*Cheilomenes sexmaculata*
10.b			*C. sexmaculata* Larva
10.c			*C. sexmaculata* Pupa
10.d			*Anegleis cardoni*
10.e			*Sticholotis cf ferrugineus*
10.f			*Brumoides suturalis*
10.g			*Coccinella transversalis*

10.h	Scarabidae	Dung beetle	*Heliocopris cf bucephalus*
10.i			*Onthophagus cf orissanus*
10.j			*Protaeita aurichalcea*
10.k			*Anomala cf dimidiata*
10.l	Meliodae	Blister beetle	*Mylabris pustulata*
10.m	Dytiscidae	Predacious diving beetle	Unidentified
10.n	Gyrinidae	Whirling beetle	Unidentified
10.o	Anthicidae	Ant-like flower beetle	Unidentified
11.a	Cicindelidae	Tiger beetle	*Calochora flavomaculata*
11.b			*Lophyra (Spilodia) striolata*
11.c			*Calochora bicolor haemorrhoidalis*
11.d			*Jansenia tetrastacta tetrastacta*
11.e			*Jansenia tetrastacta delhiensis*
11.f			*Cicindela (Pancallia) princeps*
11.g			*Cicindela (Ancylia) guttata*
11.h			*Myriochila (Myriochila)* cf *melancholica*
11.i			*Cylindera (Ifasina) viridilabris*
11.j			*Cylindera foveolata?*
11.k			Tiger beetle Larva
11.l	Erotylidae	Pleasing fungus beetle	*Episcapha sp.*
11.m	Carabidae	Ground beetle	*Subfam Odacanthini*
11.n		Bombardier beetle	*Unidentified*
11.o		Scarabidae	*Holotrichia serrata*
12.a	Cerambycidae	Round necked longhorn beetle	*Chlorophorus sp.*
12.b		Longhorn beetle	*Calothyrza margaritifera*
12.c		Sal borer beetle	*Hoplocerambyx spinicornis*
12.d	Buprestidae	Jewel beetle	*Trachys bicolor*
12.e			*Agrilus sp.*
12.f			*Psiloptera sp.*
12.g	Lampyridae	Firefly	*Luciola praeusta*
12.h			Unidentified
12.i		Firefly Female	Unidentified
12.j	Dermestidae	Carpet Beetle	Grub
12.k	Chrysomelidae	Tortoise beetle	*Aspidimorpha sanctaecrusis*
12.l			*A. sanctaecrusis* larva
12.m			*Platypria echidna*
12.n			*Dactylispa sp.*
12.o		Pumpkin beetle	*Aulacophora foveicollis*
13.a	Elateridae	Click beetle	*Cardiophorus notatus*
13.b			*Agrypnus fuscipes*
13.c			*Cryptalauss sp.*
13.d			*Campsosternus sp.*
13.e			*Lanelater sp.*
13.f	Tenebrionidae	Darkling beetle	Unidentified
13.g			*Cossyphus depressus*
13.h	Staphylinidae	Rove beetle	Unidentified
13.i	Curculionoidea	Weevil	Unidentified

	HEMIPTERA		
14.a	Aphididae	Aphid	*Aphis nerii*
14.b	Pseudococcidae	Mealybug	Unidentified
14.c	Fulgoridae	Lantern bug	Unidentified
14.d			*Dichoptera sp.*
14.e	Lophopidae		*Pyrilla cf perpusilla*
14.f	Dictyopharidae	*Lantern Fly*	Unidentified
14.g	Derbidae	Rabbit-eared bug	Unidentified
14.h	Aphrophoridae	Spittle bug adult	Unidentified
14.i		Spittle bug nymph retreat	Unidentified
14.j	Cicadidae	Cicada	*Platypleura basialba*
14.k		Cicada nymph moult	Unidentified
14.l	Psyllidae		*Heteropsylla sp.*
14.m	Ricaniidae		*Pochazia cf atkinsoni*
14.n	Flatidae	Flatid hopper	Unidentified
14.o	Kerriidae	Lac insect	*Kerria lacca*
15.a	Pentatomidae	Shield or Stink bug	*Erthesina fullo*
15.b			*Tolumnia sp.*
15.c			*Carbula scutellata*
15.d			*Bagrada hilaris*
15.e	Alydidae	Broad-headed bug	*Riptortus linearis*
15.f			*Leptocorisa oratorius*
15.g	Reduviidae	Assassin bug	*Euagoras plagiatus*
15.h			*Acanthaspis luteipes*
15.i			*Ectrychotes dispar*
15.j			*Oncocephalus sp.*
15.k			*Polididus sp.*
15.l	Cicadellidae	Rice leafhopper	*Nephotettix virescens*
15.m	Pyrrhoccoridae	Red Silk Cotton Bug	*Dysdercus sp.*
15.n			*Dysdercus sp. Nymph*
15.o	Lygaeidae	Crusader bug	*Graptostethus servus*
16.a	Scutelleridae	Jewel bug	*Chrysocoris stolli*
16.b			*Hotea nigrorufa*
16.c	Berytidae	Thread-legged bug	*Metacanthus pulchellus*
16.d	Coreidae	Leaf-footed bug	*Cletus punctiger*
16.e			*Clavigralla gibbosa*
16.f			*Dalader planiventris*
16.g			*Anoplocnemis plasiana*
16.h	Membracidae	Horned treehopper	*Otinotus oneratus*
16.i	Tingidae	Lace bugs	*Stephanitis typica*
16.j	Miridae	Leaf bug	*Lygus sp.*
16.k			Unidentified
16.l	Cercopidae	Froghopper	*Callitettix versicolour*
16.m	Rhyparochromidae	Long-necked bug	Unidentified
16.n	Notonectidae	Backswimmer	*Anisops sp.*
16.o	Corixidae	Water boatman	*Corixa sp.*
17.a	Belostomatidae	Giant water bug	*Lethocerus indicus*
17.b	Gerridae	Water strider	Unidentified
17.c	Nepidae	Water scorpion	Unidentified

17.d	Hydrometridae	Water measurer	Unidentified
17.e	Cimicidae	Bed bug	*Cimex lectularius*
	DIPTERA		
18.a	Muscidae	House fly	*Musca domestica*
18.b	Sarcophagidae	Flesh fly	*Sarcophaga sp.*
18.c	Calliphoridae	Blue Bottle fly	*Chrysomya sp.*
18.d			*Bengalia sp.*
18.e			*Stomorhina sp.*
18.f	Anthomyiidae	Anthomyd fly	*Anthomyia sp.*
18.g	Syrphidae	Hover and Flower flies	*Episyrphus sp.*
18.h			*Episyrphus maggot*
18.i			*Lathyrophthalmus*
18.j	Tachinidae	Tachinid fly	*cf Cordyligaster sp.*
18.k			Unidentified
18.l			*Mikia tepens*
18.m	Stratiomyidae	Soldier fly	*Hermetia illucens*
18.n	Chloropidae	Eye fly	Unidentified
18.o	Bombyliidae	Bee fly	Unidentified
19.a	Asilidae	Robber fly	*Neoitamus sp.*
19.b	Micropezidae	Stilt legged fly	*Unidentified*
19.c	Neriidae	Banana stalk fly	*Telostylinus sp.*
19.d	Tabanidae	Horse and deer flies	*Tabanus sp.*
19.e			*Chrysops sp.*
19.f			*Hematopota sp.*
19.g	Tephritidae	Fruit fly	*Bactrocera sp.*
19.h			*Bactrocera sp.*
19.i			*Platensina sp.*
19.j	Dolichopodidae	Long legged fly	*Chrysosoma sp.*
19.k	Drosophilidae	Common fruit fly	*Drosophila sp.*
19.l	Sepsidae	Dung fly	Unidentified
19.m	Ulididiae	Picture winged fly	Unidentified
19.n	Sciomyzidae		*Sepedon spinipes*
19.o	Phoridae	Scuttle fly	Unidentified
20.a	Celyphidae	Beetle fly	Unidentified
20.b	Diopsidae	Stalk eyed fly	*Teleopsis sp.*
20.c			*Sphyracephala sp.*
20.d	Ephydridae	Mantis fly	*Ochthera sp.*
20.e	Hippoboscidae	Louse fly	Unidentified
20.f	Lauxaniidae	Lauxanid fly	Unidentified
20.g	Culicidae	Mosquito	*Aedes sp.*
20.h	Chironomidae	Chironomid fly	*Chironomus sp.*
20.i	Tipulidae	Cranefly	Unidentified
20.j	Cecidomyiidae	Mango Gall Midge	*Procontarinia sp.*
20.k		Gnat	Unidentified
20.l	Sciaridae	Dark-winged fungus gnat	Unidentified
20.m	Bibioniidae	March fly	Unidentified
20.n	Psychodidae	Moth fly	*Clogmia sp.*

	HYMENOPTERA		
21.a	Formicidae		*Camponotus compressus*
21.b			*Camponotus sericeus*
21.c		Black crazy ant	*Paratrachina longicornis*
21.d			*Polyrhachis sp.*
21.e		Weaver ant	*Oecophylla smargdina*
21.f			*Technomyrmex albipes*
21.g			*Crematogaster sp.*
21.h			*Crematogaster sp.* Nest
21.i			*Crematogaster sp.*
21.j			*Meranoplus bicolor*
21.k		Harvester ant	*Monomorium criniceps*
21.l			*M. criniceps* Nest entrance
21.m			*Monomorium pharaonis*
21.n			*Pheidole cf watsoni*
21.o			*P. watsoni* Nest Entrance
22.a			*Myrmicaria brunnea*
22.b			*M. brunnea* Nest
22.c		Arboreal bicolour ant	*Tetraponera rufonigra*
22.d			*Diacamma ceylonese*
22.e		Procession ant	*Leptogenys processionalis*
22.f			*Leptogenys chinensis*
22.g			*Solenopsis geminata*
22.h			*Tapinoma melanocephalum*
22.i			*Pachycondyla luteipes*
22.j			*Dorylus cf labiatus*
22.k			*Dorylus cf labiatus* Male
22.l		Army ant	*Aenictus sp.*
22.m	Mutillidae	Velvet ant	Unidentified
22.n			Unidentified
22.o			Unidentified
23.a			Unidentified
23.b			Unidentified
23.c			Unidentified
23.d			Unidentified
23.e			Unidentified
23.f			Unidentified
23.g			Unidentified
23.h			Unidentified
23.i			Unidentified
23.j			Male
23.k	Myrmosidae	Velvet Ant	Unidentified
23.l	Tiphiidae		*Methocha sp.*
23.m	Crabronidae		*Trypoxylon sp.*
23.n			*Cerceris sp.*
23.o		Sand wasp	Unidentified
24.a	Vespidae		*Xenorhynchium nitidulum*
24.b			*X. nitidulum* Nest
24.c			*Rhynchiium cf sibilans*

24.d		Paper wasp	*Ropalidia brevita*
24.e			*Ropalidia marginata*
24.f		Asian Hornet	*Vespa tropica*
24.g		Potter Wasp	*Delta conoideum*
24.h			*D. conoideum* Nest
24.i			*Delta dimidiatipenne*
24.j			*Delta cf esuriens*
24.k			*Phimenes flavopictum*
24.l			*Ancistrocerus sp.*
24.m			*Antepipona sp.*
24.n			*Antepipona sp.*
24.o			*Antepipona sp.*
25.a	Braconidae	Braconid wasp	*cf Iphiaulax sp.*
25.b			Unidentified
25.c	Ichneumonidae	Ichneumon wasp	Unidentified
25.d			*Xanthopimpla sp.*
25.e			*Ischnojoppa luteator*
25.f	Euplemidae	Euplemid wasp	*Anastatus sp.*
25.g	Agaonidae	Beneficial Fig Wasp	Unidentified adult
25.h			Larva
25.i	Torymidae	Non-beneficial Fig Wasp	*Torymus sp.*
25.j	Pteromalidae	Pteromalid wasp	Unidentified
25.k	Aphelinidae	Aphelinid wasp	Unidentified
25.l	Chalciodoea	Chalcid wasp	Unidentified
25.m	Evaniidae	Ensign wasp	Unidentified
25.n	Chrysididae	Cuckoo wasp	Unidentified
25.o	Scoliidae	Scolid wasp	*Scolia cf affinis*
26.a	Apidae	Indian honeybee	*Apis dorsata*
26.b			*Apis cerana*
26.c		Pygmy honeybee	*Apis florea*
26.d		Stingless bee	*Lisotrigona sp.*
26.e		Carpenter bee	*Xylocopa sp.*
26.f		Blue banded bee	*Anthophora sp.*
26.g	Andrenidae	Mining bee	Unidentified
26.h	Halticidae	Sweat bee	Unidentified
26.i	Megachilidae	Leaf cuter bee	Unidentified
26.j	Sphecidae	Mud dauber wasp	*Sceliphron sp.*
26.k		Cricket wasp	*Sphex sp.*
26.l			*Chalybion sp.*
26.m	Pompillidae	Spider wasp	*Pepsis sp.?*
26.n			*Aporinellus sp.?*
26.o			*Tachypompilus sp.?*
	ORTHOPTERA		
27.a	Acrididae	Toothpick grasshopper	*Acrida exaltata*
27.b			*Phlaeoba infumata*
27.c			*Trilophidia annulata*
27.d			*Aiolopus thalassinus tamulus*
27.e			*Spathosternum parasiniferum*
27.f			*Eyprocnemis alacris*

27.g			*Cyrtacanthacris tatrica*
27.h			*Gastrimargus africanus*
27.i			*Stenocatantops splendens*
27.j			*Teratodes monticollis* Green morph
27.k			Brown morph
27.l			Grey morph
27.m	Tettigoniidae	Katydid	*Ducetia japonica*
27.n			*Sathrophyllia sp.*
27.o	Schizodactylidae		*Schizodactylus monstrosus*
28.a	Pyrgomorphidae		*Atractomorpha sp.*
28.b			*Chrotogonus sp.* Adult
28.c			*Chrotogonus* Nymph
28.d	Tetrigidae	Ground hopper	Unidentified
28.e			Nymph
28.f	Gryllidae	Cricket	*Gryllodes sigillatus*
28.g			*Loxoblemmus sp.*
28.h	Phalangopsidae		*Homoeogryllus indicus*
28.i	Oecanthidae	Tree cricket	*Oecanthus indicus*
28.j	Trigonidiidae	Sword-tail cricket	*Trigonidium sp.*
28.k			*Pteronemobius fascipes*
28.l	Gryllotopidae	Mole cricket	*Gryllotalpa africana*
28.m	Tridactylidae	Pygmy mole cricket	*Tridactylus sp.*
	ODONATA		
29.a	Aeshnidae	Blue darner	*Anax immaculifrons*
29.b		Blue tailed green darner	*Anax guttatus*
29.c		Parakeet darner	*Gynacantha bayadera*
29.d	Gomphidae	Common Hooktail	*Paragomphus lineatus*
29.e		Common Clubtail	*Ictinogomphus rapax*
29.f	Libellulidae	Brown dusk hawk	*Zyxomma petiolatum*
29.g		Yellow tailed ashy skimmer	*Potamarcha congener*
29.h		Long-legged marsh skimmer	*Trithemis pallidinervis*
29.i		Blue marsh hawk	*Orthetrum glaucaum*
29.j		Green marsh hawk	*Orthetrum sabina*
29.k		Granite ghost	*Bradionpyga geminata*
29.l		Ground skimmer	*Diplacodes trivialis*
29.m		Trumpettail	*Acisoma panorpoides*
29.n		Black stream glider	*Trithemis festiva*
29.o		Asiatic bloodtail	*Lathrecista asiatica*
30.a		Ruddy marsh skimmer	*Crocothemis servilia*
30.b		Coral tailed cloud wing	*Tholymis tillagra*
30.c		Wanderng glider	*Pantala flavescens*
30.d		Crimson marsh glider	*Trithemis aurora*
30.e			*T. aurora* Female
30.f		Crimson tailed marsh hawk	*Orthetrum pruinosum*
30.g		Fulvous forest skimmer	*Neurothemis fulvia*
30.h		Pied paddy skimmer	*Neurothemis tullia*
30.i		Common picturewing	*Rhyothemis variegata*
30.j		Ditch jewel	*Brachythemis contaminata*

30.k		Ruddy meadow skimmer	*Neurothemis intermedia*
30.l		Red marsh trotter	*Tramea basilaris*
31.a	Coenagrionidae	Pigmy dartlet	*Agriocnemis pygmaea*
31.b		Senegal golden dartlet	*Ischnura senegalensis*
31.c		Golden dartlet	*Ischnura aurora*
31.d		Coromandel marsh dart	*Ceriagrion coromandelianum*
31.e		Saffron-faced blue dart	*Pseudagrion rubriceps*
31.f		Blue grass dartlet	*Pseudagrion microcephalum*
31.g		Splendid dartlet	*Agriocnemis splendidissima*
31.h			*A. splendidissima* Immature
31.i		Rusty dart	*Aciagrion pallidum*
31.j	Platycnemididae	Yellow bush dart	*Copera marginipes*
31.k	Lestidae	Brown spreadwing	*Lestes umbrinus*
31.l	Calopterygidae	Black-tipped forest glory	*Vestalis apicalis*
31.o		Clear-winged forest glory	*Vestalis gracilis*
31.m	Protoneuridae	Black-winged bamboo tail	*Disparoneura quadrimaculata*
31.n		Black bambootail	*Prodasineura verticalis*
	BLATTODEA		
32.a	Blatellidae	Bush cockroach	*Blatella sp.*
32.b		Bush cockroach	*Blatella sp.*
32.c		Bush cockroach	*Bata sp.*
32.d	Blattidae	Oriental cockroach	*Blatta orientalis*
32.e		American cockroach	*Periplaneta americana*
32.f	Blaberidae		*Pycnoscelus sp.*
32.g			*Periphaeus sp.*
32.h			*Blatella sp.* scavenging
32.i			Cockroach nymphs emerging
32.j	Termitidae	Termite mound	*Odontotermes* cf *obesus*
32.k		Underground dwelling	*Unidentified*
32.l		Wood dwelling termite	Unidentified
32.m		Mound building	*O. obesus* Worker
32.n		Alate termite	Unidentified
32.o		Wood decay by termites	Unidentified
	MANTODEA		
33.a	Hymenopodidae	Praying mantis	*Creobroter sp.*
33.b		Praying mantis	*Ephestiasula sp.*
33.c		Bark mantis	*Humbertiella sp.*
33.d		Bark mantis	*Amorphoscelis sp.*
33.e	Mantidae	Stick mantis	*Schizocephala bicornis*
33.f		Praying mantis	*Statilia maculata*
33.g	Iridopterygidae		*Tropidomantis sp.*
33.h	Mantidae	Praying mantis	*Hierodula sp.*
33.i	Thespidae/Mantidae	Ground mantis	Unidentified
33.j	Mantidae	Praying mantis	*Phyllothelys sp.*
33.k		Nymph	Unidentified
33.l		Ootheca	Unidentified

	NEUROPTERA		
34.a	Chrysopidae	Green lacewing	*Chrysoperla sp.*
34.b		Eggs	*Chrysoperla sp.*
34.c		Larva	Unidentified
34.d	Myrmelontidae	Antlion	*Palpares sp.*
34.e		Antlion	Unidentified
34.f		Larva	Unidentified
34.g		Larval sand trap	Unidentified
34.h	Ascalaphidae	Owlfly	Unidentified
34.i		Owlfly	Unidentified
34.j		Larva	Unidentified
34.k		Eggs	Unidentified
34.l	Mantispidae	Mantidfly	Unidentified
34.m		Mantidfly	cf *Euclimacia* sp.
	DERMAPTERA		
35.a	Labiduridae	Earwig	*Labidura* sp.
35.b	Diplatyidae		Nymph
35.c	Labiduridae	Earwig	*Forcipula sp.*
	EMBIOPTERA		
35.d		Webspinner	Unidentified
	PLECOPTERA		
35.e		Stonefly	Unidentified
	EPHEMEROPTERA		
35.f		Mayfly	Unidentified
35.g		Mayfly	Unidentified
	TRICHOPTERA		
35.h		Caddisfly	Unidentified
	PHASMIDA		
35.i		Stick insect	Unidentified
	THYSANURA		
35.j		Silverfish	Unidentified
	THYSANOPTERA		
35.k		Thrips	Unidentified
	PSOCOPTERA		
35.l		Barklice	Unidentified
	PHTHIRAPTERA		
35.m		Louse	Unidentified
	SIPHONAPTERA		
35.n		Flea	Unidentified
	POLYDESMIDA		
36.a	Xystodesmidae	Millipede	Haraphe sp.
	SPIROTREPTIDA		
36.b	Odontopygidae	Giant millipede	Unidentified
	SPIROBOLIDA		
36.c	Trigoniulidae	Millipede	*Trigoniulus* sp.
	SCOLOPENDROMORPHA		
36.d	Scolopendridae	Centipede	Unidentified
	GEOPHILOMORPHA		
36.e	Unidentified	Soil centipede	Unidentified

	SCUTIGEROMORPHA		
36.f	Scutigeridae	House centipede	Unidentified
	SPHAEROTHERIIDA		
36.g	Sphaerotheriidae	Pill millipede	Unidentified
	ISOPODA		
36.h	Unidentified	Woodlouse	Unidentified
	ENTOGNATHA		
36.i	Collembola	Springtail	Unidentified

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Plate	Family	Common Name	Scientific name
37.a	Salticidae	Eye pattern	
37.b	Lycosidae	Eye pattern	
37.c	Ctenidae	Eye pattern	
37.d	Sparassidae	Eye pattern	
37.h	Pisauridae	Eye pattern	
37.e	Hersilidae	Eye pattern	
37.k	Gnaphosidae	Eye pattern	
37.g	Corinnidae	Eye pattern	
37.f	Oxyopidae	Eye pattern	
37.i	Thomisidae	Eye pattern	
37.j	Pholcidae	Eye pattern	
37.l	Scytodidae	Eye pattern	
37.m	Eresidae	Eye pattern	
37.p	Clubionidae	Eye pattern	
37.n	Deinopidae	Eye pattern	
37.o	Tetragnathidae	Eye pattern	
37.q	Nephilidae	Eye pattern	
37.r	Araneidae	Eye pattern	
	ARANEAE		
38.a	Salticidae	Jumping spider	*Carrhotus viduus*
38.b			*C. viduus* Female
38.c			*Carrhotus sannio*
38.d			*Hyllus semicuperus*
38.e			*H. semicuperus* Female
38.f			*cf Ptocasius yashodharae*
38.g			*Menemerus bivittatus*
38.h			*M. bivittatus* Female
38.i			*Stenaelurillus*
38.j			*Telemonia dimidiata*
38.k			*T. dimidiata* Female
38.l			*Asemonea sp.* Male
38.m			*Asemonea tenuipes* Female
38.n			*Asemonea sp.* Female
38.o			*Asemonea sp.* Female
39.a			*Harmochirus brachiatus*
39.b			*Marengo sp.*
39.c			*Marengo sp.*
39.d			*Rhene danieli*
39.e			*Rhene flavigera*
39.f			*Rhene rubigera*
39.g			*Rhene sp.*
39.h			*Rhene sp.*
39.i			*Rhene sp.*
39.j			*Plexippus paykulli*

39.k			*P. paykulli Female*
39.l			*Plexippus petersi*
39.m			*Plexippus sp.*
39.n			*Yaginumaella cf aishwaryii*
39.o			*Thyene sp.*
40.a			*Chrysilla sp.*
40.b			*Chrysilla sp.* Female
40.c			*Phintella sp.*
40.d			*Epeus indicus*
40.e			*Epocilla sp.* Female
40.f			*Hasarius adansoni*
40.g			*Phlegra sp.*
40.h			*Myrmerachne plataleoides*
40.i			*Myrmerachne sp.*
40.j			*Myrmerachne sp.*
40.k			*Myrmerachne sp.*
40.l			*Myrmerachna sp.*
40.m			*Myrmerachne sp.*
40.n			*Myrmerachne sp.*
40.o			*Myrmerachne sp.*
41.a			*Brettus sp.*
41.b			*Brettus sp.* F before moulting
41.c			*Brettus sp.* F after moulting
41.d			*Portia cf albimana*
41.e			*Cyrba sp.*
41.f	Lycosidae	Wolf spider	*Lycosa mackenziei*
41.g			*Lycosa sp.*
41.h			*Evippa sp.*
41.i			*Evippa sp* burrow
41.j			*cf Schizocosa sp.*
41.k			*Pardosa sp.*
41.l			*Trochosa sp*
41.m		Tunnel sheet spider	*Hippasa sp.*
41.n			*Hippasa sp.*
41.o			*Hippasa sp.*
42.a	Ctenidae	Wandering spider	*Ctenus sp.*
42.b			*Acantheis sp.*
42.c	Sparassidae	Huntsman spider	*Heteropoda venatoria* Male
42.d			*H. venatoria* Female
42.e			*Olios milleti*
42.f			*Olios sp.*
42.g			*cf Thelcticopis sp.*
42.h			*cf Thelcticopis* eye pattern
42.i	Pisauridae	Water spider	*Thalassius sp.*
42.j		Nursery web spider	*Perenethis cf unifasciata*
42.k			*Dendrolycosa*
42.l	Hersilidae	Two tailed spider	*Hersilia sp.* Male
42.m			*Hersilia sp.* Female
42.n	Gnaphosidae	Ground spider	*Scotophaeus sp.*

42.o	Corinnidae	Dark sac spider	*Castianeria sp.*
43.a	Oxyopidae	Lynx spider	*Oxyopes cf javanus* Male
43.b			*O. cf javanus* Female
43.c			*Oxyopes sweta*
43.d			*Oxyopes sp.*
43.e			*Peucetia viridana*
43.f			*Peucetia sp.*
43.g			*Hamadruas sp*
43.h			*Hamataliwa sp.*
43.i	Oecobiidae	Disc web spider	*Oecobius*
43.j	Pholcidae	Daddy long legs	*Crossopriza sp.*
43.k			*Pholcus sp.*
43.l	Scytodidae	Spitting spider	*Scytodes sp.*
43.m			*Scytodes sp.*
43.n			*Scytodes sp.*
43.o	Eresidae	Velvet spider	*Stegodyphus cf mirandus*
44.a	Thomisidae	Crab spider	*Thomisus sp.*
44.b			*cf Ebrechtella sp.*
44.c			*cf Diaea sp.*
44.d			*cf Camaricus sp.*
44.e			*Bomis sp.*
44.f			*Runcinia sp.*
44.g			*Xysticus sp.*
44.h			*Xysticus sp.*
44.i			*Amyciaea forticeps*
44.j	Stenochilidae		*Stenochilus sp.*
44.k	Clubionidae	Sac spider	*cf Clubiona sp.*
44.l	Oonopidae	Dwarf hunting spider	*Unidentified*
44.m	Deinopidae	Net casting spider	*Deinopis sp.*
44.n			*Deinopis* net web structure
44.o			*Deinopis* at rest posture
45.a	Theridiidae	Comb footed spider	*Theridion sp.*
45.b			*Steatoda sp.*
45.c			*Parasteatoda sp.*
45.d		Kleptoparasitic spider	*Argyrodes sp.*
45.e.		Kleptoparasitic spider	*Argyrodes sp.* Male
45.f		Mercury spider	*Argyrodes sp.* Female
45.g			*Chrysso*
45.h			*Theridula sp.*
45.i			*Theridula sp.* gum-foot web
45.j			*Theridula sp* non-sticky silk
46.a	Uloboridae	Hackled orbweaver	*Uloborus sp.*
46.b	Tetragnathidae	Long jawed orbweaver	*Opadometa fastigata*
46.c			*Leucauge decorata*
46.d			*Tetragnatha sp.*
46.e			*Tetragnatha sp.*
46.f			*Tetragnatha sp.*
46.g			*Tetragnatha sp.* Male
46.h	Nephilidae	Giant wood spider	*Nephila pilipes* Female

46.i			*Nephila pilipes* Male
46.j			*Nephila pilipes* Immature
46.k		Black wood spider	*Nephila kuhlii*
46.l		Treetrunk spider	*Herennia multipunctata*
47.a	Araneidae	Signature spider	*Argiope pulchella* Female
47.b			*Argiope pulchella* Immature
47.c			*Argiope pulchella* Male
47.d		Signature spider	*Argiope aemula*
47.e		Tent spider	*Cyrtophora sp.*
47.f			*Cyrtophora sp.*
47.g			*Araneus sp.*
47.h			*Araneus/Neoscona sp.* Male
47.i			*Neoscona sp.*
47.j			*Larinia sp.*
47.k			*Poltys sp.*
47.l			*Poltys sp.*
47.m			*Eriovixia sp.*
47.n		Debris collecting orbweaver	*Cyclosa sp.*
47.o			*Cyclosa sp.* debris in web
	SCORPIONES		
48.a	Buthidae	Scorpion	*Buthoscorpio sp.*
48.b			*Lychas* sp.
48.c	Scorpionidae		*Heterometrus* sp.
	PSEUDOSCORPIONIDA		
48.d	Unidentified	Pseudoscorpion	Unidentified
48.e			Unidentified
	OPILIONES		
48.f	Unidentified	Harvestman	Unidentified
	ACARI		
48.g	Unidentified	Forest tick	Unidentified
48.h	Trombidiidae	Red velvet mite	*Trombidium grandissinum*
48.i		Velvet mite	Unidentified

3. List of flora of KTR that attracts insects

Sr. no.	Scientific name	Type	Flowering season
1	*Crotalaria sp.*	Large Herb	Year long
2	*Tridax procumbens*	Herb	Year long
3	*Alternenthera sessilis*	Herb	Year long
4	*Calotropis gigantea*	Shrub	Year long
5	*Heliotropium indicum*	Herb	Year long
6	*Urena lobata*	Shrub	Year long
7	*Hemigraphis latebrosa*	Herb	January-April
8	*Woodfordia fructicosa*	Shrub	February-March
9	*Bombax ceiba*	Tree	February-April
10	*Butea monosperma*	Tree	February-April
11	*Erythrina suberosa*	Tree	February-April
12	*Madhuca indica*	Tree	Febraury-April
13	*Terminalia bellirica*	Tree	March-April
14	*Ficus benghalensis*	Tree	April-November
15	*Terminalia chebula*	Tree	April-May
16	*Syzygium cumini*	Tree	May-July
17	*Diospyros melanoxylon*	Tree	May-June
18	*Mitragyna parvifolia*	Tree	May-July
19	*Musa paradisiaca*	Large Herb	June-December
20	*Helicteres isora*	Shrub	July-September
21	*Pogostemon benghalensis*	Shrub	July-October
22	*Lea asiatica*	Shrub	July-October
23	*Justicia sp.*	Herb	July-September
24	*Orthosiphon rubicundus*	Shrub	July-October
25	*Impatiens sp.*	Herb	August-October
26	*Zizyphus cf mauritiana*	Shrub	August-October
27	*Celosia argentea*	Herb	August-December
28	*Clerodendrum serratum*	Shrub	August-September
29	*Commelina sp.*	Herb	August-November
30	*Abelmoschus crinitus*	Shrub	August-September
31	*Cassia tora*	Herb	August-October
32	*Sesamum orientale*	Herb	August-October
33	*Senecio sp.*	Herb	November-March
34	*Coleobrookea oppositifolia*	Shrub	November-April
35	*Leonotis neptiifolia*	Herb	December-March

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Postscript

The evolution of insects and spiders is an inevitable truth of nature: in their similicity they've become so complex in their interactions with other living and non-livng systems, I feel that a highly complex world cannot be imagined without them. Every rock and tree froms its own niche, and every possible niche is filled by insects, followed by those who depend upon them, such as spiders and birds.

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Mumbai
81/88, 'Atlanta',
Nariman Point,
Mumbai
Maharashtra 400 021
Tel. +91 22 6146 6400
info@corbettfoundation.org

Kanha
Village Baherakhar,
P.O. Nikkum, Dist.
Balaghat,
MP 481116
Tel. +91 7636 290300

Bandhavgarh
Village Bijheria, P.O.
Bandhavgarh,
Umaria,
MP 484661
Tel. +91 7627 265395

Kaziranga
Village Bochagaon,
P.O. Kaziranga,
District Golaghat,
Assam 785609
Tel. 03776-262050

Kutch
Kutch Ecological
Research Centre
P.O. Tera, Abdasa,
Kutch, Gujarat 370660
Tel. +91 2831 289305

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info@corbettfoundation.org
www.corbettfoundation.org