COMMUNITY STRUCTURE OF DUNG BEETLES IN KAILASH SACRED LANDSCAPE, PITHORAGARH, UTTARAKHAND, INDIA

Thesis submitted to the

Saurashtra University, Rajkot, Gujarat

for the award of the Degree of

DOCTOR OF PHILOSOPHY
IN
WILDLIFE SCIENCE

by
MONA CHAUHAN

Under the guidance of

Supervisor
Dr. V.P Uniyal, Scientist-G
Wildlife Institute of India, Dehradun

Co-Supervisor
Dr. Kailash Chandra, Director
Zoological Survey of India, Kolkata

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Dehradun-248001 India

February- 2020

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Dr. V.P Uniyal
Professor & Scientist-G

Dated: 05/02/2020

Certificate

Certified that the work incorporated in the thesis **"Community structure of Dung Beetles in Kailash Sacred Landscape, Pithoragarh, Uttarakhand, India"**, submitted by **Ms. Mona Chauhan,** was carried out by the candidate under my supervision/guidance. To the best of my knowledge: (i) the candidate has not submitted the same research work to any other institution for any degree/diploma, associateship, Fellowship or other similar titles (ii) the thesis submitted is a record of original research work done by the student during the period of study under my supervision, and (iii) the thesis represents independent research work on the part of the student.

Dr. V.P. Uniyal
(Supervisor)

Forwarded:

Dr. Y.V Jhala
Dean, Faculty of Wildlife Sciences

पत्रपेटी सं. 18, चन्द्रबनी, देहरादून-248 001, उत्तराखण्ड, भारत
Post Box No. 18, Chandrabani, Dehradun - 248 001, Uttarakhand, INDIA
ई.पी.ए.बी.एक्स : +91-135-2640100, 2640114, 2640115, फैक्स : 0135-2640117
EPABX : +91-135-2640100, 2640114, 2640115, फैक्स : 0135-2640117
ई-मेल/E-mail : wii@wii.gov.in, वेब/Website : www.wii.gov.in

डॉ कैलाश चन्द्र
निदेशक
Dr Kailash Chandra
Director

सत्यमेव जयते

भारत सरकार
भारतीय प्राणि सर्वेक्षण
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय
Government of India
Zoological Survey of India
Ministry of Environment, Forest and Climate Change

Date: 05 February 2020

CERTIFICATE

Certified that the work incorporated in the thesis of **Ms. Mona Chauhan,** entitled **"Community structure of Dung Beetles in Kailash Sacred Landscape, Pithoragarh, Uttarakhand, India"**, is an original piece of work submitted to the **Saurashtra University Rajkot**, for the award of **Doctor of Philosophy (Ph.D.)** in **Wildlife Sciences** from **Wildlife Institute of India** under my co-supervision. She has taken guidance from me for specimen identification at the Headquarters, Zoological Survey of India, Kolkata during the course of her research work.

Dr Kailash Chandra

Place: Kolkata

ZOOLOGICAL SURVEY OF INDIA 1916

प्राणि विज्ञान भवन, 535, एम. ब्लॉक, न्यु अलीपुर, कोलकाता – 700 053, दूरभाष : +91 33 2400 6893, टेलीफैक्स : +91 33 2400 8595
Prani Vigyan Bhawan, 535, M-Block, New Alipore, Kolkata - 700 053, Phone : +91 33 2400 6893, Telefax : +91 33 2400 8595
E-mail : director@zsi.gov.in, kailash.chandra61@gov.in, Website : zsi.gov.in

SAURASHTRA UNIVERSITY
P.G.T.R. Section
Main office,First Floor,
University Road,
Rajkot - 360 005(Gujarat)
Phone No. : 2578501
www.saurashtrauniversity.edu

Accredited Grade'A' by NAAC

CERTIFICATE FOR PRE Ph.D. PRESENTATION

This is to certify that **Ms. MONA CHAUHAN** has made Pre Ph.D. Presentation as per UGC Guideline "University Grant Commission (Minimum Standard and Procedure for award of Ph.D. Degree) Regulation – 2009" and Saurashtra university Ordinance for Ph.D. Programme (O.Ph.D. 6.2), on the Research work entitled **"COMMUNITY STRUCTURE OF DUNG BEETLES IN KAILASH SACRED LANDSCAPE, PITHORAGARH, UTTARAKHAND, INDIA''** in the Department of Wildlife Sciences, Wildlife Institute of India, Dehradun, Research Centre of Saurashtra University, Rajkot on **24th January 2020** before all the faculty members and students of the Department for getting feedback and comments

I also certify that the Research work was appreciated by all who remain present and there was no comments made for this research work.

Signature of Department Head

Name of Head: **Dr. Y. V Jhala**
Dean

Place: Dehradun
Date:

Signature of Guide:

Name of Guide: **Dr. V. P. Uniyal**
Scientist -G

Place: Dehradun
Date:

CERTIFICATE OF PLAGIARISM CHECK

01	Name of the Research Scholar	Mona Chauhan
02	Title of the Thesis	Community structure of dung beetles in Kailash Sacred Landscape, Pithoragarh, Uttarakhand, India
03	Name of the Supervisor	Dr. V.P. Uniyal
04	Institution	Wildlife Institute of India
05	Similar Content (%) identified	5%
06	Acceptable Maximum Limit	15%
07	Software Used	iThenticate
08	Date of Verification	05/02/2020

Librarian
Wildlife Institute of India

Name & Signature of the Researcher: **Mona Chauhan**

Name & Signature of the Supervisor: **Dr. V.P. Uniyal**

iThenticate
Professional Plagiarism Prevention

Mona Chauhan, Thesis, Wildlife Institute of India
By: Mona chauhan
As of: Feb 5, 2020 10:51:47 AM
44,534 words - 138 matches - 28 sources

Similarity Index
5%

Mode: Similarity Report ▼

Close Preview

paper text:

Contents Page No. List of Figures i List of Plates ii List of Tables iii List of Appendices iv Acknowledgements v Summary vi

CHAPTER 1: Introduction 1- 6 **CHAPTER 2: Review of** 2

Literature 7-21 2.1 Diversity, distribution & taxonomy of dung beetles (Scarabaeinae: Scarabaeidae) 7 2.2 Community structure of dung beetles (Scarabaeinae: Scarabaeidae) 14 2.3 Dung Beetles as bioindicator 19 CHAPTER 3: Study area, objectives and methodology 22-41 3.1 Kailash Sacred Landscape, Pithoragarh, Uttarakhand, India 22 3.2 Physical Features 22 3.3 Climate 28 3.4 Flora 31 3.5 Fauna 35 3.6 Study Period 36 3.7 Objectives 37 3.8 Methodology 37 CHAPTER 4: Community composition of dung beetles in various habitats 42-56 4.1 Introduction 42 4.2 Methods 46 4.3 Data analysis 46 4.3.1 Species richness, relative abundance and diversity pattern analysis 46 4.3.2 Cluster analysis 47 4.4 Results 48 4.4.1 Species richness, relative abundance and diversity pattern analysis 48 4.3.3.2 Cluster analysis 52 4.5 Discussion 53 CHAPTER 5: Taxonomic studies on dung beetles 57-140 5.1 Introduction 57 5.2 Methods 58 5.3 Inventory of dung beetles from KSL, Pithoragarh, Uttarakhand, India 58 5.4 Taxonomic accounts 59 CHAPTER 6: Assessment of bioindicator species of dung beetles 141-148 6.1 Introduction 141 6.2 Methods 145 6.2.1 Specimen collection 145 6.2.2 Data analysis 146 6.3 Results 147 6.4 Discussion CHAPTER 7: Mapping of important dung beetles diversity rich areas (Maximum Entropy distribution modelling) 149-176 7.1 Introduction 149 7.2 Methods 150 7.2.1 Specimen Collection and taxonomy 150 7.2.2 Data extraction and statistical analysis 151 7.3 Results 153 7.3. 1 Georeferenced environmental factors 153 7.3. 2 Area under the curve 153 7.3. 3 Response Curves 153 7.4 Discussion 174 References 177-206 List of publications and conferences presentations 207-208 List of Figures Page No. Figure 3. 1 Map showing sampling locations in Kailash Sacred Landscape, Pithoragarh, Uttarakhand, India 29 Figure 3. 2 Kailash Sacred Landscape: India, China and

Contents

List of Figures

List of Plates

List of Tables

List of Appendices

Page No.

Acknowledgements

Of the innumerable people who helped me, I take this opportunity to express my gratitude to a few of them. First of all, I would like to thank my supervisors, Dr. V.P Uniyal and Dr. Kailash Chandra, they have not only contributed directly to this study by helping me with systematic planning, study design, field work, and data collection and analysis in numerous occasions, but has provided continued support. I am especially grateful to Dr. VP Uniyal. His immense knowledge and logical way of thinking have been of great value to me. His understanding, encouragement and personal guidance have provided a good basis for the present thesis. With his enthusiasm, inspiration, and his great efforts to explain things clearly and simply, he helped me to make Wildlife Science easy for me. He has given me not only encouragement, but tremendous love and support throughout this process. Throughout my thesis-writing period, he provided encouragement, sound advice, good teaching, and excellent ideas. I could not have imagined having a better advisor and mentor for my Ph. D study.

This study was carried out as a part of the project "Kailash Sacred Landscape Conservation and Development Initiative" through a fellowship granted to me by the Wildlife Institute of India. I express my sincere gratitude to Dr. V.B. Mathur, former Director, Wildlife Institute of India and Dr. P.K. Mathur, former Dean, Faculty of Wildlife Sciences, Wildlife Institute of India for providing me an opportunity to work with the Wildlife Institute. Their generous support and guidance is greatly acknowledged. The good advice and support of Dr. P.K. Mathur, has been invaluable on both an academic and at personal level, for which I am very grateful.

I wish to convey my deep appreciation and indebtedness to Dr. Devanshu Gupta. His expertise and invaluable comments helped greatly in the completion of this thesis. Thank you "Sir" for your time, comments, and endurance for the study. I sincerely acknowledge Coleoptera section at Zoological Survey of India, Kolkata for providing all the help. I would like to thank Dr. Bitapi Sinha, Research coordinator at the Wildlife Institute of India who was always ready for help and a constant source of encouragement during the study. I sincerely thank and acknowledge the contributions of GIS cell especially Dr. Panna Lal and Ms. Alka Aggarwal during the study.

During my six year stint at WII as a doctoral student I have interacted with many colleagues for whom I have great regard, and I wish to extend my warmest thanks to all those who have helped me with my work.

Further, I would like to thank my field assistants for their unflagging love, respect and support throughout the study; this thesis would be simply impossible without them. At the Wildlife Institute of India, I would like to thank all members of the staff at the computer cell especially Shri Virendra Sharma, Library, Academic cell, Administration and Finance Departments.

I wish to thank my best friend Dr. Afshan Tarannum for helping me get through the difficult times, and for all the emotional support, camaraderie, entertainment, and caring she provided. I wish to thank Ms. Zarreen and Mr. Shuvendu Das for their help.

Last but not the least; I would like to thank my parents (Mr. Vikram Singh and Mrs. Tara Chauhan) for their continued love and support extended to me during the writing of this thesis. Special thanks to my lovely sister Kajal Chauhan who has constantly supported and loved me. She has been a constant source of inspiration, comfort and love.

This journey would not have been possible without their care and love

Summary

Dung beetles perform various ecological functions in diverse ecological services such as dung removal, nutrient cycling, bioturbation, secondary seed dispersal and parasitic control which are very useful to maintain ecosystem integrity. Dung beetles are the redistributors of nutrients, in dung decomposition and nutrient mineralization. They redistribute freshly produced dung of large herbivores between vegetation types and could therefore have an important effect on nutrient heterogeneity and cycling. Dung beetles influence seed bank dynamics by relocating the seeds under the soil surface in the process of dung removal. Dung burial is achieved through the construction of underground tunnels, and the consequent excavation of soil from deep layers to the surface. In this process, there are three types of secondary seed dispersal *viz*., accidental movement of seeds, vertical secondary seed dispersal (when seeds in dung are buried or when seeds already buried in the soil are moved along their tunnels) and vertical re-distribution upward and downward movement along the vertical axis (seeds already buried in the soil has been proposed). Beside this, dung beetles also acts as suppressor of various parasites and control population of dung dwelling flies. They also actively participate in soil dynamics by nitrogen fixation and soil aeration.

Several studies advocated dung beetles as excellent bioindicators of forest fragmentation, habitat degradation and ecosystem health. Their life history, taxonomy, ecology is well established. Their ease of detection, quantification, cost and time effectiveness also advocated the as potential indicator taxa. They are highly sensitive to disturbance and different species specialize in different habitat types and particularly vulnerable to deforestation and other changes in habitat and fauna. This sensitivity makes them as excellent focal organisms for studying the effects of anthropogenic disturbance on diversity and ecosystem function in forests because their contribution to the key ecosystem processes of dung burial and secondary seed dispersal can be measured using simple field manipulations.

Due to the recent wave of urbanization, mountain areas are being transferred into urban and agriculture land at alarming rates. The Kailash Sacred Landscape, Pithoragarh, Uttarakhand, India is highly vulnerable due to fragmentation and urbanization, including increased anthropogenic disturbance, reduced area, loss of habitats, invasion of new species and ecological transformations. Therefore, it is important to document the status of biodiversity prevailing in these areas to identify the level of biodiversity still left in forest fragments. No records exist about the community structure of dung beetles in the landscape and hence we lack crucial historical documentation of the natural communities in landscape which would remain as an important source of information for measuring species extinctions in the area.

This study provides basic inventory and diversity pattern of dung beetles from the undiscovered area of the Kailash Sacred Landscape, Pithoragarh, India. This study also suggested bioindicator based ecological monitoring and excellent insight for future conservation and management planning which will help the managers to set priority areas for habitat improvement or restrict areas to deteriorate any further.

Study area

Kailash Sacred Landscape (KSL), Pithoragarh, India part exhibits great variability and heterogeneity in altitude and topography, due to this ecosystems of this region vary widely from subtropical to temperate, alpine, and cold high altitude desert types. Similarly, the landscape harbors a high diversity of flora and fauna of both regional and global significance

The Indian part of Kailash Sacred Landscape (KSL) comprises watershed of Kali, Dhauli (east), Gori, Ramganga (east) and Saryu which fall within Pithoragarh and Bageshwar districts of Uttarakhand state. District Pithoragarh comprises eight development blocks *viz*., Munsiaryi, Dharchula, Berinag, Kanalichhina, Pithoragarh, Munakot, Gangolihat and Ghat. Likewise two developmental blocks of Bageshwar district *viz*., Mahargar and Kapkot (upper part) fall within the landscape. This landscape is a classic example of complex physiography which includes river valleys and lesser Himalayan ranges aligned in various directions. The great Himalayan ranges are mostly above 6000m a.s.l. largely aligned in northwest-southeast direction. The south-western part of the landscape is hot and semi-arid in nature while a few valleys in the central part of landscape are lush green and humid. The upland, glaciated valleys *viz*., Beans, Darma and Malla Johar have quite extensive alpine scrub and meadows, which have had a long history of human use for agriculture and animal husbandry. The western part of landscape is formed by the mountain basins of eastern Ramganga. Likewise, the Great Pancha-Chuli range, running south-east divides the basins of Gori from that of Darma Ganga (eastern Dhauli). The landscape is divisible into following major life-zones or ecoclimatic zones based on the altitude and climate: (i) Sub-tropical belt, (ii) Warm temperate (iii) Cool temperate, (iv) Sub-alpine zone, (iv) Alpine zone of greater Himalaya, (vi) Alpine arid zone of Trans-Himalaya.

Objectives

The main aim of the study is to examine the community composition and structure of dung beetles (Scarabaeinae) in various habitats and documentation of the important indicator species of dung beetles and also to highlight the importance of indicator based approach for the long term ecological monitoring.

1) **To study the community composition and structure of dung beetles in various habitats.**
2) **Taxonomic studies on dung beetles.**
3) **To assess and document the important bioindicator species of dung beetles.**
4) **To identify and Mapping of important dung beetles diversity rich areas (Maximum Entropy distribution modelling)**

Methodology

The study area has been stratified on the basis of elevation, habitat and vegetation types to explore the diversity of beetles along each gradient. Each site has been selected randomly in the various altitudinal categories so that the all types of habitats have been sampled more rigorously. The number of sampling sites has been selected at each stratum so that comprehensive representation of the dung beetles diversity at different habitats and fragment largely reflecting the local communities has been accounted.

Main Results

Of the 80 dung beetle species from Uttarakhand listed by Mittal and Jain (2015), 49 species with one new record to state (*Onthophgus hastifer*) were documented in this study. This proportion is very high considering that sampling was confined to selected micro-habitat site. The differences in community composition were mainly due to the sampling approach, as each method appeared to be sampling specific part of the beetle assemblage in a particular stratum.

The high species diversity and abundance of species is observed in Banj Oak forest (OF). It also harbors maximum species diversity followed by Alpine meadows (BG) and Fir forest (HAF) human habitation is the greater microclimatic variation in temperature, humidity and light intensity. In total, 12 species were singletons (i.e. species with only one individual collected throughout the sampling periods). The beetle community structure also alters in different habitats comparatively, Banj Oak forest and Alpine meadows exhibit highly diverse assemblages, possibly due to higher structural complexity and heterogeneity. The relatively open and availability of diverse dung pats in these habitats supported the highest number of beetle species. It was interesting to note that the species diversity follows unimodal peak in mid-elevation of the landscape. But it did not decline much in high elevation ranges the reason being the agropastrolism in the alpine meadows in monsoon (Beans, Darma, Gori & Chaudans valley).

There is another interesting finding that two species *Onthphagus dama* and *Oniticellus cinctus* are widely distributed up to mid elevation (2500m) while three species in *Liatongus* genus are most dominant in high elevation (2500m-4000m). The most abundant species are tunnellers in the study. Only four roller species (*Sisyphus, Gymnopleurus* and *Paragymnopleurus*) have been identified from the landscape. It is also believed that rollers are more superior to tunnellers. Community composition in agricultural and grassland habitat is quite distinctive from other habitat while some of these habitats share similar species composition. The reason being some large bodied dung beetles have movement rage of 2-4 km while other small species just have range of less than 1 km.

Species composition was also significantly different between sites. Since, species diversity of beetles was found to be higher in primary, mixed and alpine meadows where the greatest landscape heterogeneity occurs (interfaces of forest-agriculture landscape and grazing); such habitat heterogeneity is a determinant cause of species diversity in natural ecosystems, and therefore its preservation should be a priority when planning conservation strategies. This study highlights bioindicator based approach for long term ecological monitoring for this landscape. I found eight species indicative of the combination of forest types and elevation which can be use to assess ecosystem health of that habitat. Species distribution modeling also tried to explain the future predictions moreover precipitation was assessed as the primary driver to impact the distribution of the dung beetles in landscape.

Conclusion

Ecological data on population structure, community composition, habitat specificity of dung beetles correlated with biogeographic and historical data can be efficient model to analyze the impact of human induced changes in forest along different land use gradient, climate change and forest fragmentation. We need long-term observations and basic ecological studies to assess the impact of land management practices in the landscape. Study demonstrates that such an approach is feasible in this context. This study highlights bioindicator based approach for long term ecological monitoring for this landscape, having matrix of protected areas, dominated agriculture system and patchy habitats particularly vulnerable for climate change and land use changes.

CHAPTER 1

Introduction

Insects are among the most diverse groups of animals on the planet earth within the phylum Arthropoda. The numbers of extant species is estimated between six and ten million, and potentially represent over 90% of the differing animal life forms on Earth (Bouchard et al. 2011). Insects originated on Earth about 480 million years ago (Mosher 2007). The oldest definitive insect fossil *Rhyniognatha hirsti* is estimated to be 407 to 396 million years old (Beckemeyer & Engel 2008). They were the first animals to develop flight in the Devonian period about 400 million year ago (Orekhovo-Zuyevo 1993; Vogler 2007).

Class Insecta is divided into two sub-classes *viz*., Apterygota (wingless) and Pterygota (winged or secondarily wingless). The subclass Apterygota has four orders and sub-class Pterygota has two divisions, namely Exopterygota and Endopterygota. Exopterygota has 16 orders while, Endopterygota has 9 orders. Coleoptera by far the largest order of class insecta, with 3,50,000-4,00,000 species in four sub-orders (Adephaga, Archostemata, Myxophaga, and Polyphaga) making up about 40% of all insect species described and about 30% of all animals (Hunt et al. 2007). Against an estimated total of 179 families of Coleoptera known from the world, about 103 families are recorded from India and about 15,000 species under 2,000 genera are known from India. The National Zoological Collections in the Zoological Survey of India contains 86 families covering about 8000 species, collected from different localities in India and adjacent countries. A study based on DNA of living beetles and maps of likely beetle evolution, beetles may have originated during the lower Permian, up to 299 million years ago (Ponomarenko 1985; Shcherbakov 2008). In 2009, a fossil beetle was described from the Pennsylvanian of Mazon Creek, Illinois, pushing the origin of the beetles to an earlier date, 318 to 299 million years ago (Béthoux 2009).

The scarab beetles of the order Coleoptera include both useful (coprophagus) as well as harmful (phytophagus) insects. The coprophagus beetles generally known as dung beetles play an important role in nature's sanitation by feeding on the dung and the phytophagus beetles commonly known as chafers are pest of agricultural crops, plantation and forests. They are found in all major habitats, except marine and the polar regions. They have many classes of ecological effects; every species is adapted to particular kind of diet. Some are non specialist detritus feeders, breaking down animal and plant debris; some feed on particular kinds of carrion such as flesh or hide, dung and fungi. Some are generalist pollen, flower and fruit eaters. Some are predatory, parasites or parasitoids. The family Scarabaeidae (super family Scarabaeoidea, series Scarabaeiformia, suborder Polyphaga, order Coleoptera) includes 30,000 species worldwide (Michael & David 2004), and within Scarabaeidae, the two subfamilies; Aphodiinae and Scarabaeinae are represented by approximately 6,900 species worldwide and the subfamilies; Orphninae, Melolonthinae, Dynastinae, Rutelinae, Cetoniinae, Trichiinae and Valginae includes approximately 21,000 species (Chapman 2009).

Different beetles species that live and feed in dung, collectively known as "dung beetles". "True" dung beetles, are the members of the family

Scarabaeidae and more specifically, of the subfamily Scarabaeinae. Although many species of the closely related sister groups to the Scarabaeinae, the Aphodiinae, Geotrupidae, Hydrophilidae may also be found inhabitating the same wet dung. Dung beetles are divided into three functional groups: rollers, tunnelers and dwellers, which largely feed on dung and carrion.

Dung beetles (Scarabaeidae) compose widely distributed taxa; about 5000 species (Scholtz et al. 2009) are present worldwide. Subfamily Scarabaeinae has been classified into 12 tribes Dichotomiini (40 genera and 750 species), Onitini (18 genera and 250 species), Phanaeini (12 genera and 150 species), Coprini (ten genera and 400 species), Oniticellini (15 genera and 180 species), Onthophagini (40 genera and 2200 species), Canthonini (120 genera and 800 species), Scarabaeini (three genera and 150 species), Gymnopleurini (four genera and 110 species), Eucraniini (four genera and 16 species), Eurysternini (single genera and 20 species) and Sisyphini (three genera and 60 species) (Hanski & Camefort1991, Scholtz et al. 2009) but Dichotomiini (Halffter & Matthews 1966) were used as a tribe name but neither was described or validated in any code compliant way, therefore the name is unavailable instead of this Ateuchini is a validate tribe of dung beetles in the subfamily Scrabaeinae (Smith 2006).

Dung beetles perform various ecological functions in diverse ecological services (Nichols et al. 2008) such as dung removal, nutrient cycling, bioturbation, secondary seed dispersal and parasitic control which are very useful to maintain ecosystem integrity. Dung beetles are the redistributors of nutrients, in dung decomposition and nutrient mineralization (Edwards, 1991; Finn & Giller, 2002; Davis, 1996; Carpaneto et al.). They redistribute freshly produced dung of large herbivores between vegetation types and could therefore have an important effect on nutrient heterogeneity and cycling (Estrada & Coates-Estrada 1991; Estrada et al. 1993; Shepherd & Chapman 1998; Feer 1999; Davis et al.1999, 2000; Nichols et al. 2008;Veldhuis et al. 2018). Dung beetles influence seed bank dynamics by relocating the seeds under the soil surface in the process of dung removal. Dung burial is achieved through the construction of underground tunnels, and the consequent excavation of soil from deep layers to the surface. In this process, there are three types of secondary seed dispersal *viz*., accidental movement of seeds, vertical secondary seed dispersal (when seeds in dung are buried or when seeds already buried in the soil are moved along their tunnels) and vertical re-distribution upward and downward movement along the vertical axis (seeds already buried in the soil has been proposed) (Urrea-Galeano et al. 2019; Culotet al. 2018, 2011; Griffiths et al. 2016). Beside this, dung beetles also acts as suppressor of various parasites and control population of dung dwelling flies. They also actively participate in soil dynamics by nitrogen fixation and soil aeration.

Ecological monitoring can provide advanced warning of undesirable ecological change (climate change, forest fragmentation and biodiversity loss) thus permit managers and policy makers to adopt an adaptive management approach to conserving biological diversity. The nature of landuse changes in recent decades has not only resulted in a dramatic decrease in total forest cover, but also accelerated biodiversity loss and forest fragmentation. Forest fragmentation is a process contributing to the present-day concern over the loss of biodiversity and rates of species extinction. There is now an urgent need to identify the key effects of forest fragmentation on biotic systems and to find management solutions, for this ecological monitoring is very important to understand the complex process of biodiversity loss.

Bioindicators have been proven to be useful tools for monitoring and detecting changes in the environment. Bioindicator can be defined as a species or group of species that readily reflects the impact of environmental change on habitat, community or ecosystem or is the indicative of the diversity of a subset of taxa or the whole biodiversity within an area. Especially, living things are so closely related to the environment that the indicator between the environment and living things shows close interrelationship. Also, the indicator related to environment provides information about representative or decisive environmental phenomenon and is used to simplify complicated facts (Noss, 1990; Dufrene & Legendre 1997; Mcgeoch et al. 2002; Han et al. 2015). Considering wide range of background and application including various indicators such as the climate change, pollution, ecosystem health and species diversity, the closest category includes “environmental indicator,” “ecological indicator,” and “biodiversity indicator” (McGeoch 1998). It is impossible to evaluate the total biodiversity and also to measure the impact of environmental change on each and every species therefore we need efficient model system for analyzing the concern.

Community structure of dung beetles is largely affected by forest modification, fragmentation and elevated anthropogenic pressure hence this group clearly reflects the impact of anthropogenic pressure and habitat alteration. Community structure, population of dung beetles can be rapidly determined by using simple, standardized, time and cost effective trapping methods which permits efficient comparative evaluation of ecological changes at landscape scale. They provide an effective model to understand the effect of environmental change, habitat fragmentation or any stress.

Due to the recent wave of urbanization, mountain areas are being transferred into urban and agriculture land at alarming rates. The KSL part of Pithoragarh district, Uttarakhand, India is highly vulnerable due to fragmentation and urbanization, including increased anthropogenic disturbance, reduced area, loss of habitats, invasion of new species and ecological transformations. Therefore, it is important to document the status of biodiversity prevailing in these areas to identify the level of biodiversity still left in forest fragments. No records exist about the community structure of dung beetles in the landscape and hence we lack crucial historical documentation of the natural communities in landscape which would remain as an important source of information for measuring species extinctions in the area.

This study provides basic inventory and diversity pattern of dung beetles from the undiscovered area of the Kailash Sacred Landscape, Pithoragarh, India. This study also advocatesthe use of bioindicatorbased approach for long term ecological monitoring for conservation and management planning which can help the managers to set priority areas for habitat improvement or restrict areas to deteriorate any further.

CHAPTER 2
Review of Literature

Scarabaeinae is a very favorite group of the ecologists and taxonomists for a long time, due to their versatile habits, ecological importance in ecosystem functioning, marvelous coloration and sculpture, varied types of food habits, diverse methods of locomotion as well as their economic importance also.

2.1 Diversity, distribution & taxonomy of dung beetles (Scarabaeinae: Scarabaeidae)

Principally the studies have been carried out on evolution and ecological success, physiological and behavioral ecology, phylogeny, historical biogeography, its physical and biotic drivers and conservation of dung beetles. Studies on the taxonomy of dung beetles

The first comprehensive account on the dung beetles of Indian region on has been done by Arrow in his volume of fauna of British India (1931). Family Scarabaeidae has been described and separated from family Geotrupidae and Lucanidae on the basis of (Paulian 1945). Family Scarabaeidae was divided into two subfamilies Scarabaeinae (six tribes) and Coprinae (seven tribes) (Balthasar 1963a). Further tribes ontini, oniticellini and onthophgini was described (Balthasar 1963b). Tribe onitis (Janssens 1937), genus *Copris* (Janssens 1935), tribe oniticellini (Janssens 1953), sub family scarabaeinae (Janssens 1938), tribe Gymnopleurides (Janssens 1940), genus *Heliocopris* (Janssens 1961). Species with a special mechanism in the shape of hooked spines for covering themselves with dirt are grouped into *Sisphus* genus (Arrow 1927). Beetles taxonomic and phylogenetic research mainly based on male genitalia characters and has been applied since the beginning of 20th century, by Sharp & Muir (1912), and subsequently by Jeannel (1955), where the genital anatomy of Coleoptera was first systematized. Revision of the genus *Copris* of the western hemisphere and description of Scarabaeidae and Aphodiidae from Palaearktischen and Orientalischen Region (Matthews 1961, 1964) has been done. Tribe Onthophagini, tribe Scarabaeini and tribe Coprini have been revised with modified keys (Matthews 1972, 1974, 1976) respectively. The prevailing importance of genitalia not just in alpha taxonomy, but as reliable phylogenetic tracers against external morphological characters explicitly stressed by Zunino (1983, 1987); Zunino & Palestrini (1988). Subsequently attempt was made to describe the *Onthopagus* (Zunino 1972, 1978, 1979; Zunino & Halffter 1988, 1997). Use of male genitalia in beetles taxonomy was formally demonstrated by Tarasov & Solodovnikov (2011) by cladistic analysis of a large sample of Onthophagini. Keys to Indian subfamilies under family Scarabaeidae was also prepared on the basis of taxonomic characters and male genitalia (Mittal 1884). For the first time, all family-group names in the superfamily Scarabaeoidea (Coleoptera) are evaluated using the International Code of Zoological Nomenclature to determine their availability and validity. A total of 383 family-group names were found to be available, and all are reviewed to scrutinize the correct spelling, author, date, nomenclatural availability and validity, and current classification status. Numerous corrections are given to various errors that are commonly perpetuated in the literature (Smith 2006). Superfamily Scarabaeoidea was defined into 12 families, 43 subfamilies, 118 tribes, and 94 sub tribes. Subfamily Scarabaeinae was described into tribe Eucraniini, tribe Gymnopleurini, tribe Eurysternini, tribe Canthonini, tribe Coprini, tribe Ateuchini, tribe Oniticellini (Subtribe Drepanocerina, subtribe Oniticellina, Subtribe Helictopleurina), tribe Onitini, tribe Onthophagini, tribe Scarabaeini, tribe Phanaeini and tribe Sisyphini. In the modern taxonomy experts are following the revised classification proposed by Smith (2006). Molecular phylogeny was also introduced to define the family Scarabaeidae and the how this family evolve during the historic time (Smith et al. 2006).

In the early era of Coleopteran research, Mani (1956) had published the Entomological Survey of Himalaya about zoogeography of the high altitude insects of the Nival zones from the northwest Himalaya. He also observed that abundance and diversity of Scarabaeidae above timber-line in northwest Himalaya is sparse and makes about 4.2% of the total Coleoptera but dominant among the insects found in the Nival zone Mani (1962). Diversity and distribution of dung beetles are largely influenced by humidity, rainfall, temperature, insolation (Mittal 1981; Kakkar & Gupta 2009). In the mountains the taxa show the phenomenon of zonal stratification where altitude acts as the delimiting factor. This altitudinal zonation is possible because of the confinement of a taxon to a certain altitude belt and various factors that control its distribution; are essentially those which are associated with altitude, such as temperature, humidity, atmospheric pressure, etc. It has been observed that the zones of distribution of various species are limited to narrow belts in higher altitudes; while at lower elevations the species mostly show wide ranges of distribution. In the higher altitudes, where species are adapted to a particular climatic condition, smaller fluctuations in the limiting factors tell upon them more severely that in the case of lower altitudes where only more pronounced changes in the environmental factors are able to impress upon the taxon (Mittal 1981). Elevation gradient is also one of the important limiting factor determining the distributional pattern for dung beetles in mountains (Alvarado et al. 2014; Escobar et al. 2007). Elevation is also related to climate effects, such as temperature, rainfall regime and light intensity, and to the biogeographical history of the region. As a response to these environmental factors related to elevation, physiological restrictions can determine the spatial distribution of species (Barragán et al. 2014). Zonal stratification ultimately leads to endemism (Sabu et al. 2011a).

North West India shows maximum number of diversity and richness, various studies concluded that Indian Gangetic plains harbors maximum species richness (Mittal & Bhati 1998; Mittal & Vadhera 1998; Mittal 1999; Mukhi 2002; Mittal (1981a, 1981b, 1999, 2000, 2005). Classification and taxonomy of Scarabaeidae has been reviewed from the Oriental region and synoptic key for the 18 subfamilies represented from India (Mittal 1984). 33 species from Sonti Reserve Forest and Seonsar Reserve Forest, Haryana have been described (Jain & Mittal 2012).

Synoptic key of 77 species of the dung beetles (subfamily Scarabaeinae) from Western Uttar Pradesh has been described (Mittal 1999). About 136 species representing 26 genera from eight subfamilies from north

India (Haryana, Punjab, Himachal Pradesh, Uttarakhand and Uttar Pradesh) (Mittal 2005) have been identified. Taxonomic significance of the external male genitalia of some species of the genera; *Catharsius*, *Onthophagus* and *Oniticellus* have been studied (Sewak 1985a, 1985b, 1986a, 988). About 102 species belonging to 14 genera under tribe Coprini and Scarabaeinae from have been recorded from Rajasthan (Sewak 2009b), Later, nine species from Talchappar Wildlife Sanctuary, Rajasthan (2009c) and 28 species belonging to 11 genera from Ranthambhore National Park (Sewak 2010) have been demonstrated. A comprehensive account of 66 species of the dung beetles has been prepared from the Thar Desert of Gujarat (Sewak 2009a). Altogether 55 species under 13 genera are included of which seven species as new to science and 48 species have been described and three species of *Onthophagus* remained undescribed are recorded from Namdapha National Park, Arunachal Pradesh (Biswas & Chatterjee1985). Later 73 species belonging to 14 genera were included with description of identification keys to all the tribes, genera and species of Arunachal Pradesh was described (Sewak 2006). About 115 species of dung beetles belonging to 17 genera describing 28 species as new to science, including the identification keys to all the taxa have been described from the state Meghalaya (Biswas & Ghosh 2000).

27 species of dung beetles belonging to within eight genera from Tripura (Chatterjee & Biswas 2000) and two species in genus *Catharsius* from Sikkim has been reported (Chatterjee & Biswas 2003). 16 species of the dung beetles belonging to under subfamily Scarabaeinae from silent valley of Kerala have been documented(Biswas & Chatterjee 1986). 88 species of the

dung beetles from Biligiri Rangaswamy Temple Wildlife Sanctuary, Karnataka have been described (Rajan 2006). Later two species within 19 genera of subfamily Scarabaeinae described from Tamil Nadu (Chandra 2009c). 22 species of dung beetles have been reported from Bandhavgarh National Park, Madhya Pradesh (Chandra & Ahirwar 2005, Chandra 2009b), 66 species from Madhya Pradesh (Chandra 2000), 54 species from Pachmarhi Biosphere Reserve (Chandra 2009b), 66 species from Madhya Pradesh and Chhattisgarh (Chandra & Ahirwar 2007; Gajendra & Prasad 2015). A well-documented taxonomic record of the dung beetles of Madhya Pradesh and Chhattisgarh (Chandra 1999, 2007; Chandra & Singh 2010; Chandra & Gupta 2011a, 2011b, 2011c, 2012a, 2012b, 2012c) exits which illustrates diversity and distribution of these beetles in different protected areas of the state.

Five species have been described from tropical montane cloud forests of Eravikulam National Park by Sabu et al. (2011). Coastal area also attracted dung beetles taxonomists and 49 species have been identified from Gujarat (Sewak 2004). Some efforts have been made by taxonomists to explore the mountains, studies on the species composition and density of entomofauna, indicator species along altitudinal variations and disturbances of Coleopterans. Insects in the high altitude ecosystems of the Indian Himalayan regions have been carried out by Mani (1956); Singh (1963); Joshi et al. (2004); Chandra (2005); Joshi et al. (2008, 2014); Chandra et al. (2012). Around 40 species have been described from Himachal Pradesh, in which *Onthophagus* genus was most diverse (Mittal 2000). Deserts also harbors a rich diversity of dung beetles about 102 species have been identified from Rajasthan (Sewak 2009a, 2009b, 2009c, 2010). A survey of scarab beetle faunal diversity, abundance and composition were studied in Kolkas region of Melghat Tiger Reserve, Amravati, Maharashtra, about 26 species of scarab beetles belonging to 14 genera and 8 subfamilies were identified (Thakare et al. 2011).

Destruction and deterioration of natural habitats associated with urbanization has led to dramatic changes in the biotic structure and composition of ecological communities (Venugopal et al. 2012). Forest fragmentation leads to structural changes in the community structure of dung beetles (Halffter et al. 1992; Escobar 2000; Davis et al. 2000, 2001; Halffter & Arellano 2002; Davis 2000; Nummelin & Hanski 1989; Halffter et al. 1992; Davis et al. 2000, 2001; Klein 1989; Davis 1994; Estrada et al. 1999; Didham et al. 1998; Estrada et al. 1999; Didham 1996, 1997a, b; Andresen 2003, 2005). The changes depends on the degree of fragmentation and how continuous or natural forests are modified into the fragmented patches. Similarly second order or functional effects of altered dung beetle communities such as dung removal rate, secondary seed dispersal and nutrient recycling. Dung beetles exploit patchy and ephemeral dung pats as resources and hence strong competition between co-occurring species plays a major role in structuring communities (Feer & Pincebourde 2005). Many species occur in large populations, and dung beetles occupy diverse ecological niches due to their dung foraging tactics and life history traits. Since dung beetles depend generally on dung produced mainly by mammals, such resource can be extremely patchy in space and time (Sabu et al. 2006, 2007). Hence, resource partitioning and competition are prime features of dung beetle species assemblages (Hanski 1991). Microclimatic conditions also effect the distributional pattern and population dynamics of dung beetles. Selective logging, grazing and forest fire and conversion of forested areas into plantations or agroforestry alters the microclimatic conditions of a particular habitat (Doube 1991; Hanski & Cambefort 1991; Barbero et al. 1999; Gardner et al. 2008; Shahabuddin et al. 2010; Slade et al. 2011). Apart from land use, seasonality is another key factor that may influence populations, especially in the tropics, due to temporal variation in temperature, rainfall and resources availability (Spector 2006; Damborsky et al. 2015; Batista et al. 2016). Species richness, assemblages and abundance are also affected by the landscape matrix and habitat heterogeneity. At landscape scale, the sensitivity of dung beetles to landscape structure could be observed in the different species responses to landscape matrix type. The matrix surrounding habitat patches can affect species dispersal ability, pattern and competition among the metapopulations (Ricketts 2001; Haynes et al., 2006; Schmidt et al., 2008) and, by extension, population persistence within patches (Fahrig 2001; Murphy & Lovett-Doust 2004). These effects are observed mainly in habitat specialists that avoid the matrix and are more prone to decline within habitat patches than species able to exploit the matrix (Gascon et al. 1999; Schtickzelle et al., 2007; Numa et al. 2009). Trophic resources and their availability, rate of dung renovation and dung amount/quantity, seems to determine the local variation in dung beetle diversity and composition of dung beetle assemblages in a landscape (Verdú et al. 2002; Verdú & Galante 2002; Lobo et al. 2006).

2.2 Community structure of dung beetles (Scarabaeinae: Scarabaeidae)

Destruction and deterioration of natural habitats associated with urbanization and infrastructure development have led to drastic changes in the biotic structure and composition of ecological communities (Didham et al. 1996). Spatial and temporal distribution of dung beetle community is determined by several physical and biotic factors, dispersal corridors, barriers and invasion into new territories. Habitat modification and fragmentation comprise two of the most common types of landscape conversion. The former involves the direct alteration of a habitat as a result of human activities whereas the latter involves the reconfiguration of a habitat into smaller, isolated patches within a matrix of modified habitat (Nichols et al. 2007). Forest fragmentation leads to conversion of natural or continuous forests into forest patches of different size (Roslin & Koivunen 2001; Shahabuddin et al. 2005). This reduces the total area of habitat, creates subpopulation of species and species interactions and ecological process are disrupted (Andresen 2003, 2005). Altered temperature, humidity, or soil characteristics as a consequence of habitat disturbance may directly impact beetle species (Davies & Margules 1998). Dung beetles from different functional groups may respond to changes in vegetation structure in different ways, as habitat openness can directly increase the desiccation rate of dung pats and nest balls, potentially restricting the rollers and dwellers to more shaded areas (Louzada et al. 2010; Vullnec 2002). Fragmentation can also have important effects on the vertical stratification on the dung beetle community. Some arboreal dung beetle species seem to be able to cope with forest disturbance by moving closer to the forest floor while specialist arboreal species do not have the versatility to cope with such a change (Tregidgo et al. 2010).

Isolation and fragmentation induced changes in forest structure may cause the disruption of those biological processes that maintain biodiversity and ecosystem functioning, such as pollination, seed dispersal and nutrient recycling (Turner 1996). Land use changes also reduce the dung beetles richness, abundance and biomass, consequently their dung burial ability, affect the interaction between dung beetles and flies as well as decreases its effectiveness as a natural biological control (Klein 1989). Changes in food resources also transform the community structure of dung beetles (Carpaneto et al. 2005). As the dung beetles respond to environmental changes, the community found was never the same all the time. Seasonal factors affect the structure of the community by changing the species occurrence and abundance and their seasonal and phenological cycles. Community structure of dung beetle is directly correlated to dung type, seasonal conditions and soil type. The daily weather factors also have some short term effects. The cause of variation in population has been assigned to several other factors, such as, dispersion in different microhabitat, age of the dung, time of the day and time of the year, and also because of the odour, consistency and wetness of the dung (Mittal & Vadhera 1998; Mittal & Kakkar 2005). Less openness in vegetation cover acts as a filter that prevents penetration by flying species (Lumaret & Kirk, 1987). At the same time it reduces the dispersion of dung odour cues (Romero-Alcaraz & Ávila 2000) and causes microclimatic changes (Galante et al. 1993) that affect the dung colonization process restricting, for example, species by their thermoregulation capacity (Verdú et al., 2007; Numa et al. 2009).

Large body size is one of the most commonly cited traits promoting extinction over ecological time scales, and has been reported in both vertebrates and invertebrates, including dung beetle studies on the effects of fragmentation and forest clearance (Rosenlew & Roslin 2008; Larsen et al. 2005). Larger bodied dung beetles are more vulnerable than smaller bodied species to abundance declines, if not local extinctions, due to the fragmentation of primary forest to secondary or agroecosystem (Gardner et al. 2008). Reasons could be low fecundity and reproductive rates and long lifespan. The non-random impact on dung beetle body-sizes is reflected in the different responses of abundance and biomass to trophic resource availability, suggesting that both abundance and biomass data should be used in future studies (Tonelli et al. 2018). Specialists and rare species have specific ecological habitat requirements, making them more sensitive to extinction. Because of sparse or patchy distribution, species are also more likely to be absent from a patch when it was initially fragmented within the landscape. Small populations are also more susceptible to environmental changes and stochasticity (Larsen et al. 2008). In tropical forests, human-induced changes influence dung beetles by deleteriously affecting the survival of forest-restricted species and by allowing forest invasion by native and introduced species of open areas. More forest-restricted species persist where more tree cover remains. There is a gradient of decreasing richness of forest-restricted species and increasing richness of open area species (Halffter & Arellano 2002).

Fragment characteristics such as vegetation structure, litter depth, age, and isolation distance may influence the communities of dung beetles and influence the ecological roles of the species too. Litter depth and density are transformed due to the logging, road clearings and construction. Declined litter supply with decreased canopy cover and increased runoff due to soil compaction modify soil characteristics such as moisture, texture, density, and nutrient composition, which may increase the recruitment and/or reproduction of dung beetles. Some studies have also suggested that dung beetle species are generally unable to exploit modified habitats exhibiting high temperatures and diurnal fluctuations in light (Hosaka et al. 2014a). Road clearings and selective loggings have a negative effect on the efficiency of secondary seed dispersal and other ecological functions performed by dung beetles (Hosaka et al. 2014b).

Fragmentation mediated changes in community structure can also trigger trophic cascades that affect species at many levels of the food web, often leading to further extinctions and ecosystem decay (Nyeko 2009). Various studies (Hanski & Cambefort 1991; Estrada & Coates-Estrada 1991; Estrada et al. 1993; Estrada et al. 1994; Hill 1996; Treitler et al. 2017) have suggested if dung resources are limited as a result of the general scarcity and patchy distribution of dung-producing mammals and dung beetles compete intensively for resources as attested by their competitive and combative behaviors (Estrada & Coates-Estrada 2002). A pattern of resource partitioning that arises from the mechanism of niche pre-emption is frequently found in harsh ecosystems, where individuals compete for access to scarce resources, and has been therefore successfully employed to explain the species-abundance distributions of several dung beetle assemblages that depend on typically ephemeral resources (Macagno & Palestrini 2009). Dung beetles are important predators and parasitoids of various flies, it has been observed when dung beetles and horn flies co-occur, fly survival rate tends to decrease as a consequence of asymmetrical resource competition and mechanical damage of eggs by beetles (Ridsdill- Smith & Hayles 1987, 1990). Dung pad size, potential of anoxic and fluidic conditions of pad influences adult and larvae of dung beetles in a holistic manner. Studies indicate that there is greater crowding by adult dung beetles in larger, fresh dung pads. However, despite equivalent levels of crowding by young larvae in pads of different sizes, there appeared to be more crowding by older larvae in larger pads. It can be stated that lower surface area volume ratio of larger pads possibly has dissimilar consequences for the adult and larval life stages. Thus, it may be that the tolerance by adults of relatively unfavorable conditions in larger pads is a trade-off for the greater suitability of larger pads for larvae (Gittings 1994; Gittings & Giller 1997, 1998; Finn & Paul Giller 2000). Edge-affected habitats and open-habitat matrices are suitable for a very limited subset of generalist forest-dependent species while disturbance-adapted species occurring almost exclusively in those habitats (Filgueiras et al. 2015). Multiple edges profoundly influence community structure as modified habitats that provide low environmental heterogeneity, can result in biotic homogenization (Melo et al. 2013). This will ultimately promote an alternative form of community-level taxonomic divergence (Filgueiras et al. 2016).

2.3 Dung Beetles as bioindicator

Several studies suggested criteria to select the indicator taxa such as adequate baseline information should be established. Taxon’s biology and taxonomy should be well understood. In addition, clear correlation between the taxon's responses to evaluate ecosystem alterations must be established (Pearson & Cassola 1992). Selected taxa should also have a cosmopolitan distribution for cross-comparisons of different habitats. A taxon should have low variability both genetically and ecologically, so that random fluctuations in populations nor species adaptations could impede the studies. All the above stated criteria have been fulfilled by dung beetles (Scarabaeidae: Scarabaeinae). Their life history, taxonomy, ecology is well established. Their ease of detection, quantification, cost and time effectiveness also advocated the as potential indicator taxa. They are highly sensitive to disturbance and different species specialize in different habitat types and particularly vulnerable to deforestation and other changes in habitat and fauna. This sensitivity makes them as excellent focal organisms for studying the effects of anthropogenic disturbance on diversity and ecosystem function in forests (Finn 2001; Halffter & Favila, 1993; Spector 2006), because their contribution to the key ecosystem processes of dung burial and secondary seed dispersal can be measured using simple field manipulations (Nichols et al. 2008; Slade et al., 2007, 2011; Urrea-Galeano et al. 2019).

Dung beetles have been investigated for their ecological functions to assess and predict the true environmental consequences of human activities, ecosystem health, global warming and climate change. Dung beetles also show strong spatial specializations (warmer, moister, climatic regions). Climatic variables (temperature, humidity, rainfall) also exerts a major influence on dung beetle diversity at regional scale. At local scale, both soil and vegetation type are also influential on dung beetle distribution (Davis & Scholtz 2001). Organisms that control ecological processes at any single location, or in any particular year, often differ from those that control processes in other locations or years. It has been suggested that more biodiversity is required to maintain the 'multi-functionality' of ecosystems at multiple places and times (Slade et al. 2016.). This itself defines the role of bioindicator, being an important contributors in the ecosystem functioning it also reflects the state of others taxon' effective influence in the ecological processes. Correlation with other taxa: Focal taxa that are to be used as indicators of overall levels of invertebrate diversity, endemism, or endangerment should have geographic patterns of species richness and endemism that closely reflect those of other taxa within the study region (Spector 2006). This could be explained on the basis that some species of dung beetles shows strong associations with microhabitat conditions and resources, and many of them cannot shift their populations to degraded habitats or they have certain range boundaries. Hence this drives functional change in the community structure/ assemblages/composition and consequently hampers the ecosystem functioning.

Chapter 3

Study area, objectives and methodology

3.1 Kailash Sacred Landscape, Pithoragarh, Uttarakhand, India

Kailash Sacred Landscape (KSL), Pithoragarh, India part exhibits great variability and heterogeneity in altitude and topography, due to this ecosystems of this region vary widely from subtropical to temperate, alpine, and cold high altitude desert types (Fig. 3.1, Plate No.1-2). Similarly, the landscape harbors a high diversity of flora and fauna of both regional and global significance

3.2 Biophysical features

The Indian part of Kailash Sacred Landscape (KSL) comprises watershed of Kali, Dhauli (east), Gori, Ramganga (east) and Saryu which fall within Pithoragarh and Bageshwar districts of Uttarakhand state. This sector of Indian Himalaya finds reference in ancient Vedic literature as "Bharat Khand" that formed part of Aryavrat. Administratively this landscape falls under eastern Kumaon and bounded by Kingdom of Nepal in the east, Tibet Autonomous region (TAR) of People Republic of China (PRC) in the north, Champawat district of Uttarakhand in the south and Almora district in the west (Fig 3.2). Two sub-watersheds of Ganges *viz*., upper Pindar and Girthi Ganga have been included in this landscape. District Pithoragarh comprises eight development blocks *viz*., Munsiaryi, Dharchula, Berinag, Kanalichhina, Pithoragarh, Munakot, Gangolihat and Ghat. Likewise two developmental blocks of Bageshwar district *viz*., Mahargar and Kapkot (upper part) fall within the landscape.

Plate No. 1

Study Area Landscape

Plate No. 2

Study Area Landscape

This landscape is a classic example of complex physiography which includes river valleys and lesser Himalayan ranges aligned in various directions. The great Himalayan ranges are mostly above 6000m a.s.l. largely aligned in northwest-southeast direction. The south-western part of the landscape is hot and semi-arid in nature while a few valleys in the central part of landscape are lush green and humid. The upland, glaciated valleys *viz*., Beans, Darma and Malla Johar have quite extensive alpine scrub and meadows, which have had a long history of human use for agriculture and animal husbandry. The western part of landscape is formed by the mountain basins of eastern Ramganga. Likewise, the Great Pancha-Chuli range, running south-east divides the basins of Gori from that of Darma Ganga (eastern Dhauli). A sub-ordinate but prominent ranges of Pancha-Chuli i.e., Balchidhura-Chhipla and Najuri lie between Gori and Kali basin towards lower end. On the northeast, Chhota Kailash, a snowy range divides Darma Ganga and Kutti-Yangti, Chhota-Kailash also called Ardh-Kailash is connected towards lower area by Yuchikang range, where some of the peaks rise to the height of over 6000m a.s.l. River Kali the largest river in Kumaon that forms international boundary with Nepal upto Sharda also has a large catchment in latter especially Api and Nampa Peaks. A considerable area in the upper part of this landscape falls under erstwhile Askot Wildlife Sanctuary (AWS; 600 km2; 29o45' to 30o25' N lat and 80o15' to 80o50' E long) which was notified by the Government of Uttar Pradesh under G.O. No. 996/14-3-30/84 dated 30.07.1986 for the conservation of regional flora and fauna (Arya 1991). This sanctuary covers upper watersheds of Kali, Dhauli and Gori with an altitudinal range of about 1400m a.s.l. near Paiyapaur to 6,700m a.s.l. (Pancha Chuli II).

The landscape is divisible into following major life-zones or ecoclimatic zones based on the altitude and climate: (i) Sub-tropical belt, (ii) Warm temperate (iii) Cool temperate, (iv) Sub-alpine zone, (iv) Alpine zone of greater Himalaya, (vi) Alpine arid zone of Trans-Himalaya. Characteristic features of these zones are summarized below:

(i) Sub-tropical zone: The low-lying warm valleys below 1000m a.s.l. are characterized by climate that is similar to that of tropics, except that these areas have a short and mild winter when minimum temperature (January) may drop to 8-10°C. Depending upon the corridors and connectivity. These zone exhibits close affinities with the flora and fauna of Bhabar belt of Uttarakhand. Notable species include Red jungle fowl, King Cobra, *Shorea robusta*, *Terminalia chebula* and *T. bellirica* among others. Major corridor's connectivity of this linking the Bhabar belt is through the Sharada Valley. The river Sharada (lower stretch of Mahakali) harbours a great deal of affinities with Upper Gangetic plains in terms of aquatic fauna.

ii. The Warm Temperate Zone: The inter-montane valleys and low hills roughly between 1000-2200m a.s.l. which are characterized by prominent winters (mean minimum temperature in January up to 2-3°C), fall under this category. Two species of trees *viz*., Banj oak (*Quercus leucotrichophora*) and Chirpine (*Pinus roxburghii*) form the climax species of forest vegetation in this belt depending upon the geology, soil and frequency of fire.

iii. The Cool Temperate Zone (2200-3000m a.s.l.): This zone represents the upper montane region marked by a prolonged and severe winter with heavy snowfall during winter that may stay on the ground for 2-3 months. Also, the summers are wet owing to local convections. The forests are generally broad-leaved, deciduous as well as evergreen. Few south facing, steeper slopes support coniferous forests and anthropogenic grasslands. This zone is quite rich in flora and fauna, typical of mid elevation zone in Western Himalaya.

iv. Sub-alpine Zone (3000-3500m a.s.l.): This is a narrow belt between the cool temperate and alpine zones, often terminating at a natural timberline. Depending upon the exposition, topography and degree of anthropogenic pressures, the elevation and nature of timberline ecotone varies considerably. Being at the junction of two major life zones the sub-alpine belt harbours the species from both the regions. Besides, several species of flora and fauna in this region can be used as indicators for monitoring the changes in the habitat conditions and climate in the region, notably, *Rhododendron barbatum*, *Piptanthus nepalensis*, *Angelica glauca*, *Triosteum himalayanum*, *Syringa emodi*, *Calanthe tricarinata*. Among faunal species, Himalayan musk deer, Royle’s pika, Himalayan monal and others typically represent this zone.

v. Alpine Zone of Greater Himalaya (3600-5000m a.s.l.): The area between natural tree line and snowline in the region represents one of the district and fascinating biomes on account of extremely harsh climatic conditions, stark seasonality and patterns of adaptations (morphological and physiological) among the biota. The area remains under snow for 4-6 months where mean minimum winter temperature goes several degrees below zero. The alpine zone is home of a large number of high value medicinal and aromatic plants, which are collected by the local communities to earn cash income. Alpine Zone also harbours a large number of threatened and endangered species.

vi. Alpine Arid Regions: The trans-Himalayan region lying to the north of Great Himalayan massif, especially in the upper catchment of Girthi Ganga; Kyo-gar, Sangcha Malla and areas adjacent to Tibetan Plateau harbours sparse vegetation cover and very primary productivity. Unlike most alpine zone of Greater Himalaya, the alpine arid pastures have low species diversity. The typical faunal elements in this region include endanger Snow leopard (*Panthera uncia*), Blue sheep (*Pseudois nayaur*), Red fox (*Vulpes vulpes*), Tibetan snowcock (*Tetraogallus tibetanus*), most of which move freely across the larger landscape covering Tibetan Autonomous Region of PRC and NorthWest Nepal.

3.3 Climate

The study area typically exhibits temperate and alpine climate. Most of the area (60%) falls under alpine zone, which remains snow covered during winter months (November-March). The year can be categorised into four seasons *viz.*, summer, Summer or hot weather (mid March-mid June), monsoon (mid June-September) and winter or Cold weather (mid December-mid March), season of general rains (South-West monsoon season), season of retreating monsoon (mid September-mid November). Rains are mostly confined to (South-West monsoon season). The mean monthly temperature ranges from 20-35°C in summer season, while it varies from 5.5-8.0°C during the winters.

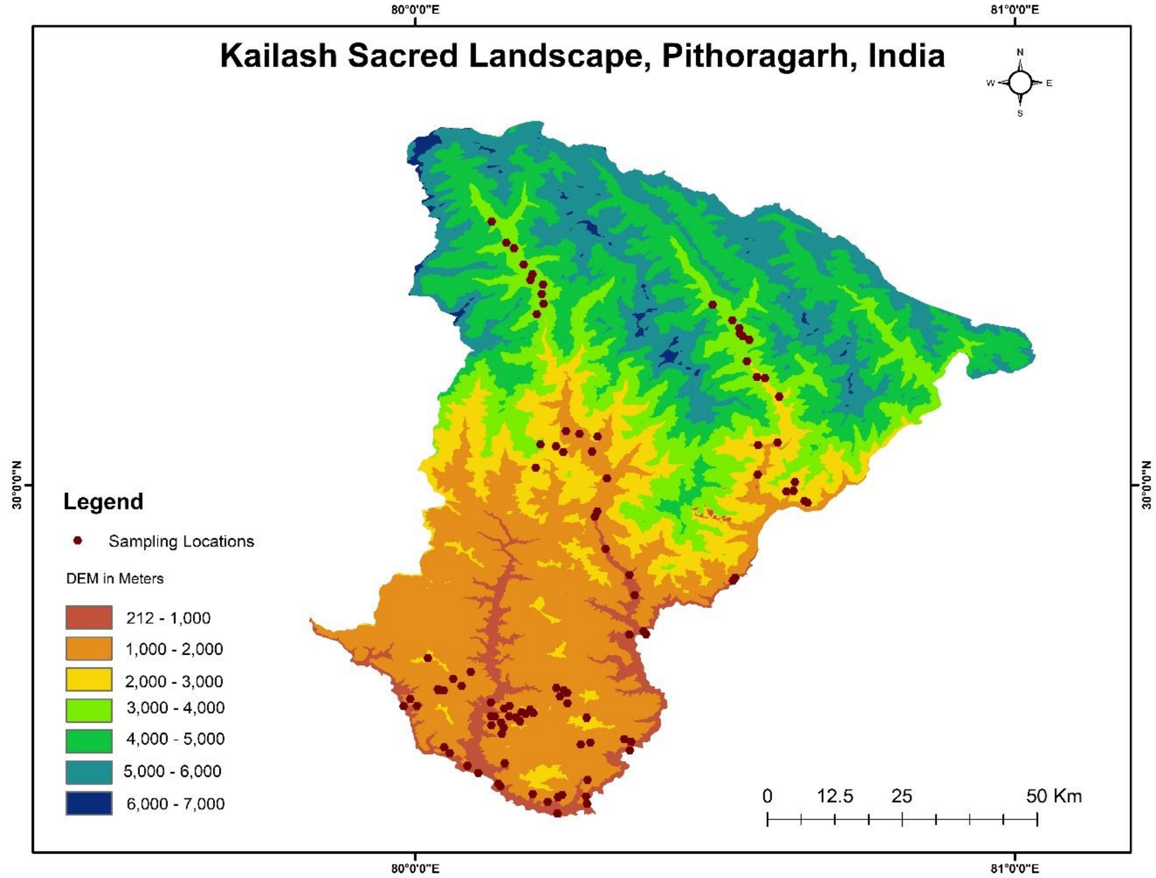


Figure 3.1 Map showing sampling locations in Kailash Sacred Landscape, Pithoragarh, Uttarakhand, India

Figure 3.2 Kailash Sacred Landscape: India, China and Nepal

3.4 Flora

This landscape harbours a diverse vegetation types ranging from the categories similar to Tropical moist Deciduous Forests to alpine moist and dry pastures. Physiognomically, the forests, scrub (natural and secondary), grasslands (natural and anthropogenic) and alpine meadows represent major categories which are further divisible into a number of communities/subclasses (Table 3.1). Some of the classes and their Champion and Seth's (1968) equivalents are given below:

Table 3.1 Major Vegetation types in KSL, India

S.N.	**Vegetation Type**	**Corresponding C&S Category**	**Characteristic Species**
1.	Sal Forest	5B/C1a: Dry sal bearing forests	*Shorea robusta*, *Litsea monopetala*, *Terminalia alata*, *Mallotus phillippensis*
2.	Pine Forest	9/C1b: Himalayan Chir pine forest	*Pinus roxburghii*, *Woodfordia fruticosa*, *Glochidion velutinum*
3.	Sub-tropical Riverine Forests	Not described	*Toona ciliate*, *Macaranga pustulata*, *Engelhardtia spicata*
4.	Banj Oak Forest	12/C1a: Banj oak forest	*Quercus leucotrichophora*, *Myrica esculenta*, *Dendrobium spp.*, *Lyonia ovalifolia*, *Sinarundinaria falcate*,
5.	Moru (Timsu) Oak	12/C1b: Moru oak forest	*Quercus floribunda*, *Symplocos chinensis*, *Thamnocalamus falconerii*, *Sorbus vestita*,
6.	Kharsu Oak	12/C2a: Kharsu oak forest	*Quercus semecarpifolia*, *Taxus wallichiana*, *Prunus cornuta*, *Thamnocalamus spathiflorus*,
7.	Alder Forest	12/1S1 *Alnuns nepalensis* forests	*Alnus nepalensis*, *Pilea umbrosa*, *Debregeasia hypoleuca*,
8.	Cypress Forest	12/E1 *Cupressus torulosa*	*Cupressus torulosa*, *Lespedeza gerardiana*, *Pogonatherum paniceum*,

9.	Temperate Grassy slopes	12/DS3: Himalayan Secondary Grasslands	*Themeda anathera, Chrysopogon gryllus, Cymbopogon distans, Andropogon munroi,*
10.	Hemlock (Tansen) Forest	Not described	*Tsuga dumosa*
11.	Temperate Secondary Scrub	12/DS2 Temperate Parkland C1/DS1: Oak Scrub C1/DS2:Himalayan Temperate Secondary Scrub	*Quercus leucotrichophora, Berberis asiatica, Prinsepia utilis, Rubus niveus,*
12.	Temperate Broadleaf Forests (Moist Deciduous)	12/C1 West Himalayan Temperate Forests	*Acer villosum, Betula alnoides, Juglans regia, Aesculus indica*
13.	Blue Pine (Kail) Forest	13/C4: West Himalayan High-level Dry Blue Pine Forest	*Pinus wallichiana, Juniperus communis*
14.	Sub-alpine Forest	14/C1: West Himalayan Subalpine Birch/Fir Forest (Betula/Abies) Birch-Rhododendron Scrub Forest	*Rhododendron campanulatum, Betula utilis, Lonicera sp., Rosa macrophylla,*
15	Alpine Scrub	15/E1: Dwarf rhododendron scrub 16/E1: Dwarf juniper scrub	*Rhododendron anthopogon, Cassiope fastigiata, Salix denticulate, Salix lindleyana, Lonicera myrtillus,*
16.	Alpine Pastures	15/C3: Alpine Pastures (Dry and moist types)	*Danthonia cachemyriana, Potentilla argyrophylla, Kobresia sp., Trachydium roylei,*

The KSL, India is bestowed with varied vegetation types ranging from tropical moist deciduous to alpine vegetation. In the lower altitude region up to 800m a.s.l.), moist tropical and dry deciduous forest of Sal (*Shorea robusta*) mixed with Syzygium, Aegle, Haldina, Acacia and Terminalia are found. At places, scrub forests having evergreen species are also found. The dominant trees in the region are *Shorea robusta*, *Syzygium cumini* (Jamun), *Anogeissus* *latifolia* (Bakli), *Aegle marmelos* (Bael), *Haldina cordifolia* (Haldu), *Mitragyna parvifolia* (Kaim), *Mallotus phillippensis* (Rohini), *Madhuca longifolia var. latifolia* (Mahua), *Dalbergia sissoo* (Sheesham), *Ficus religiosa* (Peepal), *F. auriculata* (Timla), *F. semicordata* (Khainu), *F. virens* (Pakad), *F. benghalensis* (Bargad), *Acacia catechu* (Khair), *Albizia lebbeck* (Siris), *Terminalia alata* (Asna, Asain), *T. bellirica* (Bahera), *Oroxylum indicum*, *Holoptelea integrifolia* (Dhamina), *Streblus asper* (Sehore), *Diospyros melanoxylon*, *Butea monosperma* (Dhak, Palas), *Buchanania lanzan* (Chirongi), *Cassia fistula* (Amaltas), *Lannea coromandelica* (Jigma Jhingan), *Pongamia pinnata* (Karanj), *Sterculia spp*. etc.

With an altitudinal increase a change in the vegetation is clearly visible. Higher up between 1000-3000m a.s.l mixed forest of *Rhododendron arboreum*, *Quercus leucotrichopora* (Banj), *Lyonia ovalifolia* (Anyar) and *Myrica esculenta* (Kaphal) are first to appear. In between *Viburnum cotinifolium*, *Symplocos paniculata*, *Lonicera quinquelocularis*, *Neolitsea umbrosa*, *Cornus macrophylla*, etc. are also seen mixed up. The undergrowth constitutes *Sarcococca saligna*, *Daphne cannabina*, *Coriaria nepalensis*, *Deutzia staminea*, *Myrsine africana*, *Elaeagnus sp*. together with herbaceous elements. *Pinus roxburghii*, is the first to make appearance among the gymnosperms. These mixed forests are followed by *Quercus dilatata* (Tilonj), *Q. semecarpifolia* (Kharsu), *Prunus puddum* forest with species of *Ilex excels* (Tumari) and *Aesculus indica* (Pangar) and *Carpinus viminea*. Some trees, Cotoneasters and *Juglans regia* (Akhrot) also make scattered appearance. At certain places pure strands of *Pinus roxburghii*, *Cedrus deodara*, *Taxus wallichiana* and *Abies pindrow* (Ransula) make a sight to watch. On dry slopes *Pyrus pashia*, *Prinsepia utilis*, *Berberis lycium* and *B. chitria* are dominant.

The herbaceous growth at this altitude mainly consists of *Morina longifolia*, *Anemone obtusiloba*, *A. vitifolia*, *Podophyllum hexandrum*, *Corydalis sp*. *Paeonia emodi*, *Paris polyphylla*, and species of *Geranium*, *Viola*, *Valeriana*, *Bergenia*, etc. Species of *Cypripedium*, *Pleione*, *Calanthe* and *Cardiocrinum giganteum* are occasionally noticed. Another orchid *Gastrochilus distichus* makes frequent appearance on *Quercus sp.* *Phalaenopsis taenialis* is also seen perching on *Albizia sp*. and *Lyonia ovalifolia* at some places. *Rubus paniculatus*, *Hedera nepalensis*, *Cayratia trifolia*, *Smilax glaucophylla*, *Clematis sp*. *Dioscorea sp.* etc. are the common climbers while *Holboellia latifolia*, *Schisandra grandiflora* and *Sabia campanulata* are seen occasionally. *Jasminum dispermum* and *Aristolochia dilatata* are also seen hanging from rocks. Still higher up is *Betula utilis* (Bhojpatra) that forms the tree limit in this part of Himalaya.

Above this altitude shrubby or herbaceos plants like species of *Hippophae*, *Juniperus*, *Saussurea*, *Primula*, *Corydalis*, *Pleurospermum*, *Rheum*, *Rhododendron anthopogon*, *Meconopsis aculeata*, etc. make the vegetational cover. It is interesting to note that several forest formations given in the table are found only in this district and have not been reported from other parts of Western Himalaya for example, Hemlock (*Tsuga dumosa*) stands in and around Askot Wildlife Sanctuary exhibits affinities of this landscape with that of central and eastern Himalaya and this landscape happens to be the westernmost limit of *Tsuga* in the Himalaya. In the lower riverine areas, Gori and Kali valleys there are extensive stands of *Macaranga* *pustulata*. This fast growing gregarious species is also typical of eastern Himalayan foothills. The middle to high elevation riverine areas support a number as *Hippophae salicifolia, Debregeasia hypoleuca, Salix wallichiana, Myricaria germanica* and *Hippophae tibetana*. Among the climax communities, five species of oaks occupy the different habitats at successive altitudes *viz*., *Quercus glauca* (<1500m a.s.l, riverine areas); *Q. leucotrichophora* (1100-2200m a.s.l; gentle, south facing slopes); *Q. lanuginosa* (1500-2000m a.s.l; confined to selected belts of the landscape adjacent to *Q. leucotrichophora*); *Q. dilatata* (2200-33000m a.s.l; shady moist slopes), *Q. semecarpifolia* (2800-3500m a.s.l; Gentle, south-facing slopes often forming timberline). Among various forest formations, Banj oak forms most prominent community in the district that has undergone tremendous anthropogenic pressure for fuel wood, fodder and land reclamation.

3.5 Fauna

Over 35 species of mammals (excluding chiropterans and some rodents) have been reported to occur in this landscape. Assamese macaqu (*Macaca assamensis*), Snow leopard (*Panthera uncia*), Common leopard (*Panthera pardus*), Himalayan wolf (*Canis himalayensis*), Eurasian otter (*Lutra lutra*), Blue sheep (*Pseudois nayaur*), Himalayan musk deer (*Moschus chrysogaster*), Himalayan tahr (*Hemitragus jemlahicus*), Serow (*Nemorhaedus sumatraensis*), Goral (*Naemorhaedus goral*) are the major species found in the landscape. This landscape forms the extreme limits of their natural distribution and also there is lack of information on their current status and distribution. About 155 species of birds, four species namely Satyr Tragopan (*Tragopan satyra*), Cheer Pheasant (*Catreus wallichii*), Red-headed Vulture

(*Sarcogyps calvus*) and Egyptian Vulture (*Neophron percnopterus*) are listed as vulnerable in the IUCN Red list of threatened species (IUCN, 2014). Various species of fishes, deep bodied Mahseer (*Tor tor*) and Golden Mahseer (*Tor putitora*) are threatened and vulnerable due to intensive dynamiting and may get further endangered due to upcoming hydro-power projects unless adequate conservation measures are taken. Some of the amphibians which can be encountered occasionally in Gori and Kali valleys includes: *Duttaphrynus himalayanus*, *Duttaphrynus melanostictus*, *Xenophrys parva*, *Amolops formosus*, *Amolops marmoratus*, Nanorana liebigi, *Nanorana polunini* (Least concern); *Nanorana ercepeae* (Near Threatened); *Nanorana minica*, *Scutiger nepalensis* (Vulnerable) and two Data Deficient species, *viz*., *Polypedates teraiensis*, *Chirxalus dudhwaensis*. 86 morphospecies of insects under 39 genera and 17 families including 25 species of spiders have been described (Uniyal et al. 2010).

3.6 Study period

Intensive field work has been done in Kailash Sacred Landscape, Pithoragarh from March 2016 to September 2018. Sampling has been carried out along the elevation gradient from 400m a.s.l to 4000m a.s.l covering diverse forest types during different seasons to understand the diversity and distribution pattern of dung beetles in the area. Four valleys *viz*., Chaudans, Darma, Gori, Beans and lower elevation ranges of KSL, India have been covered.

3.7 Objectives

The main aim of the study is to examine the community composition and structure of dung beetles (Scarabaeinae) in various habitats and documentation of the important indicator species of dung beetles and also to highlight the importance of bioindicator based approach for the long term ecological monitoring.

1) **To study the community composition and structure of dung beetles in various habitats.**
2) **Taxonomic studies on dung beetles.**
3) **To assess and document the important bioindicator species of dung beetles.**
4) **To identify and Mapping of important dung beetles diversity rich areas (Maximum Entropy distribution modelling)**

3.8 Methodology

The study area has been stratified on the basis of elevation, habitat and vegetation types to explore the diversity of beetles along each gradient. Each site has been selected randomly in the various altitudinal categories so that the all types of habitats have been sampled more rigorously. The number of sampling sites has been selected at each stratum so that comprehensive representation of the dung beetles diversity at different habitats and fragment largely reflecting the local communities has been accounted.

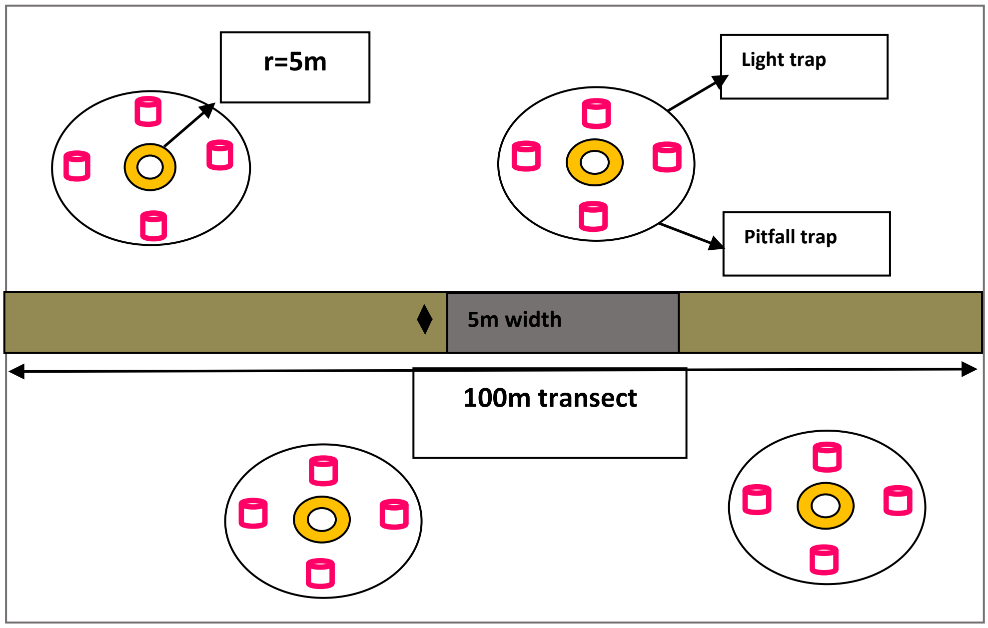


Figure 3.3 Sampling methodology

Four sample plots sampling unit grid with 20m radius have been marked on each linear transect measuring 100m in length and 2m in width in each habitat along existing trail in the forest. Thus, there is one transect containing four sample plots. The spatial distance between two transects in each has been maintained at minimum 100m (Fig. 3.3).

Sampling methods

Dung beetles have been collected by the various sampling methods *viz.*, pitfall trap, hand picking and light trap. Pitfall and light traps have been deployed in the center of each sample unit. These sample plots have been monitored during winter, summer, and monsoon seasons to obtain consistent and reliable data.

Monitoring the abundance of dung beetles is increasingly valuable to understand their population dynamics, plan management strategies and assess the attainment of conservation targets. There are many sampling techniques for the collection of dung beetles like handpicking, pitfall trapping and light trapping. All of these techniques have been used to collect dung beetles from different habitat. These sampling techniques have no detrimental impact on longer-term trend of dung beetle population, since no intensive sampling of a highly localized species has been done.

A. Handpicking

Small beetles have been collected by hand either with the help of a fine brush or by a forceps. Hand picking needs searching in particular habitat like in dung, scat and pellets get the representative population of dung beetles (Davies & Stork 1996).

B. Trapping

A trap is defined as anything that impedes or stops the progress of an organism; this subject is extensive, including devices used with or without baits, lures, or other attractants. Mostly pitfall traps and light traps are used to collect dung beetles. The performance of a trap depends on such factors as its location, time of year or day, weather, temperature, and kind of attractant used (Halsall & Wratten 1988). Trapping has been done with the help of pitfall traps and light traps to study the aerial dispersal and other biological phenomenon.

C. Pitfall trap

Pitfall traps have been used to study the surface dwellers. It consists of glass, plastic or metal container, sunk into the soil so that mouth is level with the soil surface. Beetles falling into trap are unable to escape. The efficiency of pitfall trap depends upon the level of trap lip and the retaining efficiency. Artificial or natural baits can be used in pitfall traps. Baited traps have been found more useful for collecting beetles from different habitats (Briggs 1960).

Traps have been filled with liquid preservative (69 % water, 30% ethyl acetate and 1% detergent). Formalin, alcohol, picric acid and aqueous solution of tri-sodium phosphate can be used as bait. A grid of traps can provide an impressive set of data. The number of beetles trapped depends upon population density movement and outer boundary of area. The trap catches may be more effective by the color of trap. The pitfall traps have been open for a period of two days, as this allows maintenance of beetles in good conditions before they could be transported to the laboratory for their identification. However, the limitations of this method are that the number of individuals trapped is affected by environmental, weather and species-specific factors. Despite the various limitations pitfalls have been used in this study because they are widely used, cost effective and operate on a full time basis (active during day and night) (Topping & Sunderland 1992).

D. Light trap

Light traps are used for general survey of dung beetle diversity, and these usually are simple interception devices that capture beetles moving through an area. Light traps have been used to determine the presence of primarily nocturnal species of dung beetles as well as nocturnal activity of otherwise diurnal species and for the monitoring of the beetle population.

A simple light trap is consists of an exposed cone funnel, killing bottle and a fluorescent tube. Funnel will be placed on the cone, light tube is placed above the funnel and killing bottle is connected to the funnel. Beetles attracted by light will fall down into funnel and finally will be collected in the killing bottle. The trap sites have been selected in the center of plots with a homogeneous vegetation cover, so that the catches at different habitats and fragment should largely reflect the local communities. The minimum distance between neighboring sites have been maintained 100m, with lamps not being visible from neighboring sites (Barr 1963), so that cross-habitation sampling does not occur. At each site sampling has been done for two days at different vegetation type to collect sample from each stratum. Light trap catches are strongly influenced by the weather and lunar cycle. Yella & Holyoak (1997) suggested restriction of the light trapping before or after five days of full moon light. Williams et al. (1936) also recognized that at the time of a full moon fewer beetles caught the light traps than at the time of a new moon. According to Williams (1936) the reasons for a smaller catch at a full moon might be as follows (a) Moonlight reduces the activity of beetles and so the active population accessible for the light trap is smaller (b) The light of the lamp collects beetles from a smaller area in a moonlight environment.

E. Preservation

Collected beetles have been preserved beetles are preserved in 70% alcohol, with a few drops of ethyl acetate after which they have been pinned. Pinned beetles have been shifted to permanent wooden cabinets having a ball dipped in the solution of camphor and carbolic acid (3:1) and naphthalene surrounding. This will protect the beetles from any fungous infection.

CHAPTER 4
Community composition of dung beetles

4.1 Introduction

Across fragmentation studies, dung beetle species richness, abundance and evenness declined in smaller forest fragments. Richness and abundance sometimes declined in more isolated fragments, although this response appeared to depend on matrix quality. Fragments with impoverished tree communities (particularly shade-tolerant species) support impoverished dung beetle communities (Filgueiras et al. 2011). Land use changes affected beetle species composition by altering habitat structure (e.g., litter layer) and the availability of feeding resources. Heavily modified habitats with little or no tree cover support species-poor dung beetle communities with high rates of species turnover, dramatically altered abundance distributions and smaller over-all body size from those found in intact forest (Nichols et al. 2007; Jellinek 2013). Dung beetle assemblages are often sensitive to habitat change and disturbance can have significant effects on species diversity, abundance, biomass and species dominance (Botes et al. 2006; García-Tejero et al. 2013). Dung beetles assemblages also depend on the availability of wild mammals in the primary forests (Estrada1998). When Jay-Robert et al. 2008 compared the density of trophic resource in the habitats, (ii) the regional dung beetle fauna and the distribution of species among the habitats and (iii) the density of beetles in natural droppings and the evenness of assemblages. High diversity, high species density in droppings and high evenness were observed in grazed shrub land, whereas fewer species were observed in deer lumps. Results clearly showed that, while wild ungulates manure is not enough to ensure the conservation of the regional dung beetle species pool, the spatial habitat heterogeneity of grazed shrub land allows the local coexistence of numerous species (Jay-Robert et al. 2008).

Selective changes in mammalian biomass and composition affect dung beetle species abundance, richness and composition, which in turn may have cascading consequences for the ecosystem .The maintaining of species-rich and even distributed dung beetle communities through the conservation of large mammals would allow conserving more efficient functional ecosystem services such as soil aeration, secondary seed dispersal or parasite regulation than with the sole or dominated presence of small dung beetles since large ones were shown to be faster and more efficient in removing dung (Edwards & Aschenborn 1987). Dramatic changes in mammalian composition in most tropical ecosystems are thus likely to drive severe second-order effects altering basic ecosystem functioning that are urgent to be investigated (Culot et al. 2013; Van Rensburg et al. 1999; Martikainen et al.2000).

Dung removal rates were significantly and positively correlated with dung beetle species richness, but not with dung beetle biomass or abundance. Similarly, less efficient recycling of nitrogen from the soil surface is likely to have contrasting effects on different plant taxa. low-intensity sustainable logging does not appear to have long-term detrimental effects on dung beetle diversity, composition and functioning at our study site. However, high intensity logging appears to have had a more marked effect, with reduced species richness and functioning (França et al. 2017). An emerging trend across such studies is that larger-bodied dung beetles contribute disproportionately to ecosystem functioning. These taxa are also more susceptible to habitat disturbance than smaller species with potentially important consequences for ecosystem functioning (Slade et al. 2011; Hill 1996; Lumaret et al. 1992).

It was also observed that dung beetle body length is positively correlated with the amount of dung consumed and area requirements, larger bodied beetles are more vulnerable to habitat fragmentation. Larger dung beetles use a disproportionately larger share of resources and therefore may be negatively affected by reductions in resource in altered habitats.

External threats from agricultural intensification, fire encroachment, species invasion and illegal harvesting present major conservation challenges in isolated tropical forest remnants. These processes can greatly exacerbate the magnitude of edge effects as the degree of patch to matrix contrast increases. One study from tropical rainforest reserve suggests that while vegetation structure significantly affected up to 34 m from the road edge, impacts on dung beetle communities penetrated much further and were discernible up to 170 m into the forest interior (Edwards et al. 2017). Edges could be used as buffer by species influenced by this process and there may be increase in the abundance along the edges (Barnes et al. 2014). Species with a low population density may have a problem surviving in small pastures due to a high local extinction risk. This might be of minor importance in landscapes with a high density of pastures, such as in traditionally managed landscapes, but will be even more severe when small pastures are highly isolated, Pastures which have been grazed for hundreds of years often show equal proportions of habitat specialists and generalists. Thus, existing low-intensity pastures which have been grazed over centuries are of high value for the conservation of dung beetle species (Buse et al. 2015).

Strong intra and interspecific competition have been observed under certain density conditions, which resulted in a marked reduction in resource (dung) acquisition. role of competition (for resources) as a force structuring communities, one must therefore establish the frequency, duration and intensity of competition between species and determine the direct and indirect consequences of such competition interspecific competition for dung is frequently observed in the field (Miller 1961; Hugheset al.1975; Peck & Howden1984; Giller & Doube1994; Chown et al.1995; Davis & Sutton 1997). Some species of dung beetles can use a wide range of food sources, from carrion to dung or more specific resources such as mushrooms, fruits, diplopods and decomposing vegetation. Other species are highly specialized, using certain mammal dung (Noriega 2012).

It is evident from the previus studies (Wolda 1987; McCoy 1990) that altitudinal gradient plays critical role in distribution for both in entomofauna and other species (Janzen et al. 1976; Terborgh 1977, 1985). It may be beacause of the limiting effect of environmental varibales at low and high altitudes and to the contact at mid-altitiude between speies of low and high altitudes. Varius drivers that have been put forward to explain the latitudinal gradients of species richness (e.g. productivity gradient, differences in history, spatial heterogeneity, environmental variability, etc.) can also be applied to the altitudinal gradients (Pianka 1966; Rohde, 1992).

4.2 Methods

Dung beetles were collected by the various sampling methods *viz*., hand sorting, pitfall trap and light trap as previously discussed (Section 3.8). Digital elevation map has been used to identify and sample the all the altitudinal categories from 400m a.s.l. to 4000m a.sl. List of the sampling locations have been provided in Appendix 4.1 and also marked in Fig. 3.1.

4.3 Data analysis

4.3.1 Species richness, relative abundance and diversity pattern analysis

Measurement of Alpha diversity (α-diversity)

Alpha diversity (α-diversity) is the biodiversity within a particular area, community or ecosystem, and is usually expressed as the species richness of the area. This can be easily measured by counting the number of taxa (distinct groups of organisms) within the ecosystem. However, such estimates of species richness are strongly influenced by sample size, so a number of statistical techniques can be used to correct for sample size to get comparable values. Shannon index H' was used to measure diversity across the selected micro-habitats. It provided the information entropy of the distribution, treating species as symbols and their relative population sizes as the probability. The advantage of this index is that it takes into account the number of species and the evenness of the species. The index is increased either by having additional unique species, or by having greater species evenness. Shannon J' provided the species evenness that is the relative abundance or proportion of individuals among the species. Fisher's α often recommended as the most reliable assessment of alpha diversity referring mostly to show superior discrimination ability between sites and, most relevant has no relationship (above a relatively low threshold) with sample size (n) in replicates from the same site.

4.3.2 Cluster Analysis

Multidimensional scaling (MDS) is a set of related statistical techniques often used in information visualization for exploring similarities or dissimilarities in data and can be considered to be an alternative to factor analysis. MDS is thus a special case of ordination. An MDS algorithm starts with a matrix of item–item similarities, and then assigns a location to each item in Ndimensional space, where N is specified a priori. Multidimensional scaling (MDS) plots were constructed based upon similarity values of species composition across habitat types in software program R. MDS uses an algorithm which successively refines the positions of the points until they satisfy, as closely as possible, the dissimilarity between samples. The result is a two dimensional ordination plot where points that are close together represent samples that are very similar in composition. Points that are far apart correspond to samples with very different composition.

4.4 Results

4.4.1 Species richness, relative abundance and diversity pattern analysis

Measurement of Alpha diversity (α-diversity)

Land use matrix always affect species diversity and richness, it is observed for this landscape too. It is observed that Banj Oak forest (OF) harbors maximum species diversity followed by Alpine meadows (BG) and Fir forest (HAF) (Fig 4. 1) while least in human habiation.

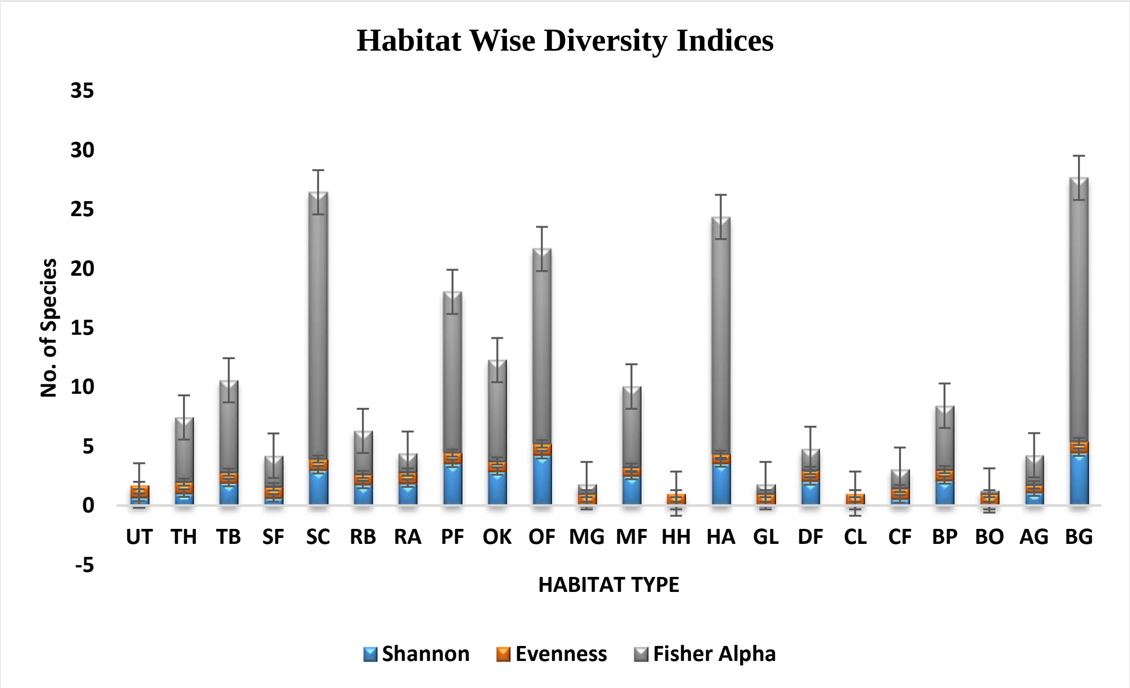


Figure 4. 1 Index values for Shannon H’, Shannon J’ and Fisher’s α obtained for the sampled habitats across KSL, India.

It is also observed by uniqueness value that mixed forest (MF), human habitation (HH), Sal forest (SF), grassland (GL) harbor certain specialist species restricted to particulary that habitat in the landscape (Fig. 4. 2)

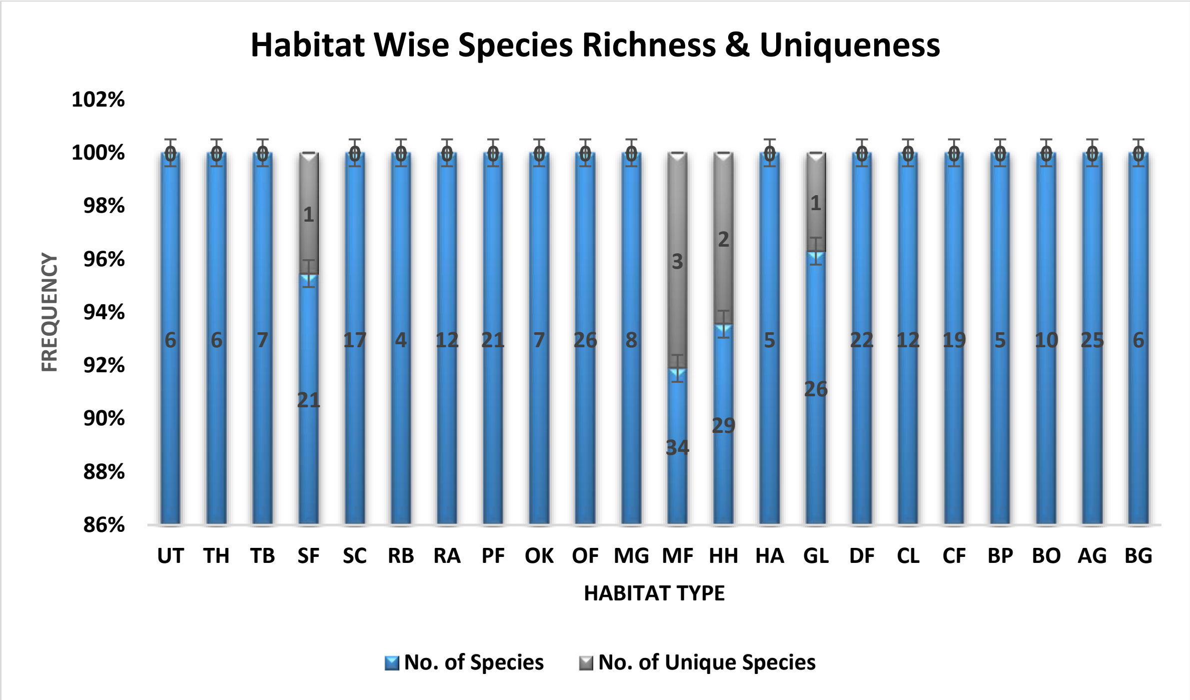


Figure 4. 2 Habitat wise species richness and uniqueness obtained for the sampled habitats across KSL, India.

It has observed that *Oniticellus cinctus* (sp.18) is highly abundant followed by *Onthophagus (Colobonthophagus) dama* (sp.30), *Onitis philemon* (sp22), *Liatongus mergacerus* (sp.16), *Liatongus phanaeoides* (sp.17) and *Tiniocellus spinipes* (sp.19) in the study area (Fig 4.3).

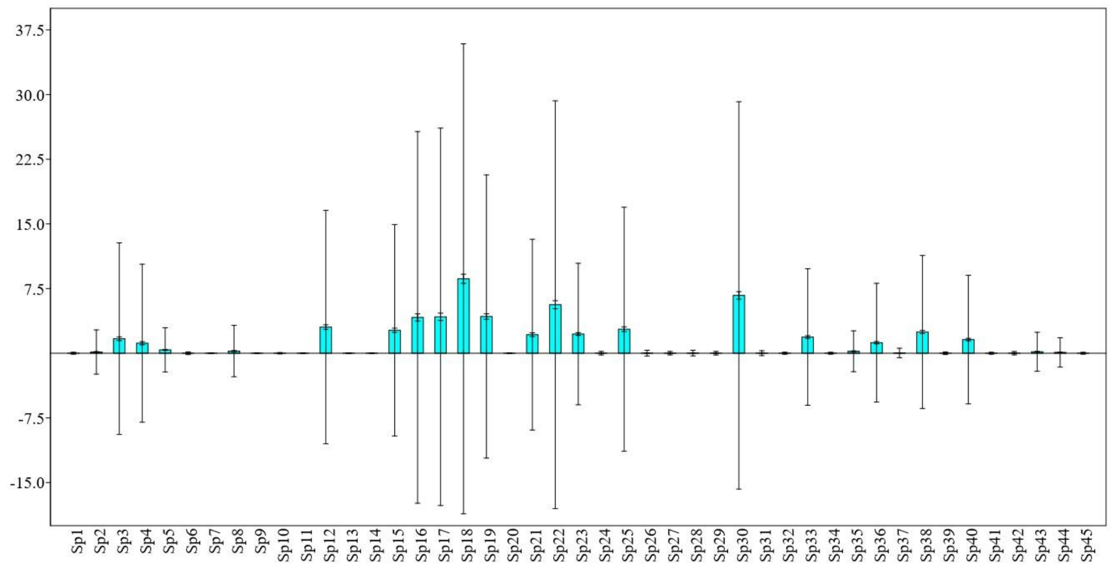


Figure 4. 3 Habitat wise species abundance obtained for the sampled habitats across KSL, India.

It is observed that there is no unimodal peak in species diversity in the mid-elevation but there is another unique trend that after mid elevation diversity of dung beetles did not decline much because in this landscape high elevation peaks are mostly alpine meadows. In KSL, agropastrulasits usually migrate to Alpine meadows in rainy season with their livestock. The dung from livestock supports high diversity in the region lead to this high diversity in the landscape (Fig. 4. 4).

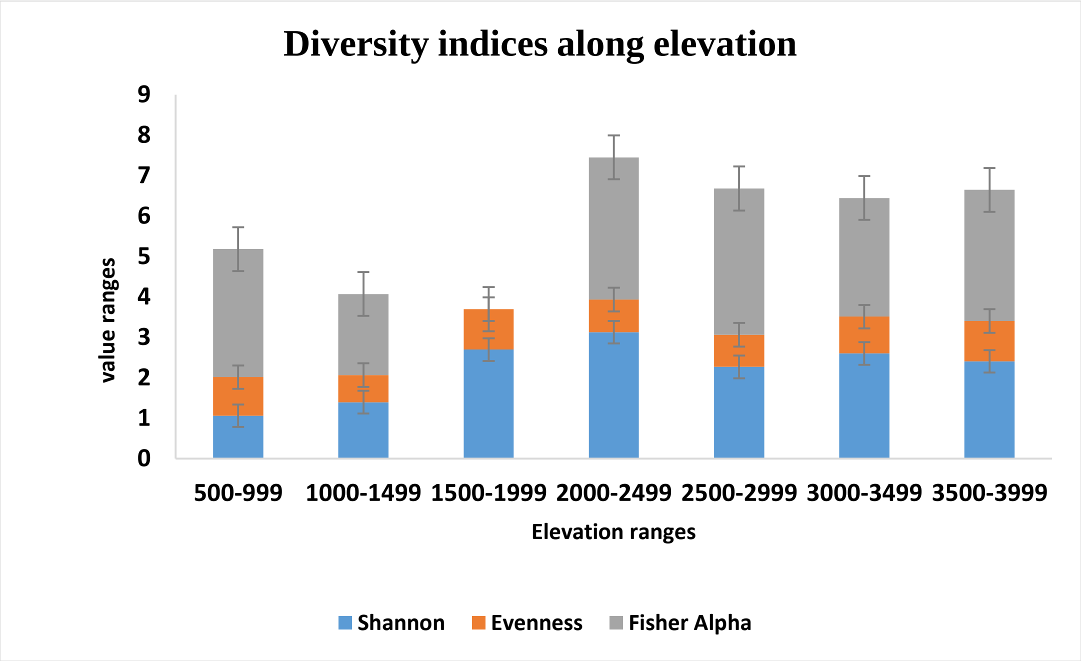


Figure 4. 4 Index values for Shannon H', Shannon J' and Fisher's α obtained for the sampled along elevation ranges across KSL, India.

4.4.2 Cluster Analysis

Comparing different sites revealed that on an average, species composition was much more similar within the same habitat type than among different habitat types. MDS plot generated from relative abundances of different beetle species in pooled habitats showed that sampling sites from each habitat type were distinctly segregated (Fig. 4.5) and that the sampling sites of agriculture (AG) and grassland (GL) were well separated. Pine forest (PF) and Banj Oak forest (BF were nearer in the ordination. Kharsu Oak forest (KF) and Fir forest (HAF) were again showed little overlap with other habitat types (Fig. 4. 5). MDS ordination of species according to habitat types mostly showed pattern of separation of species in habitat space with little degree of overlap.

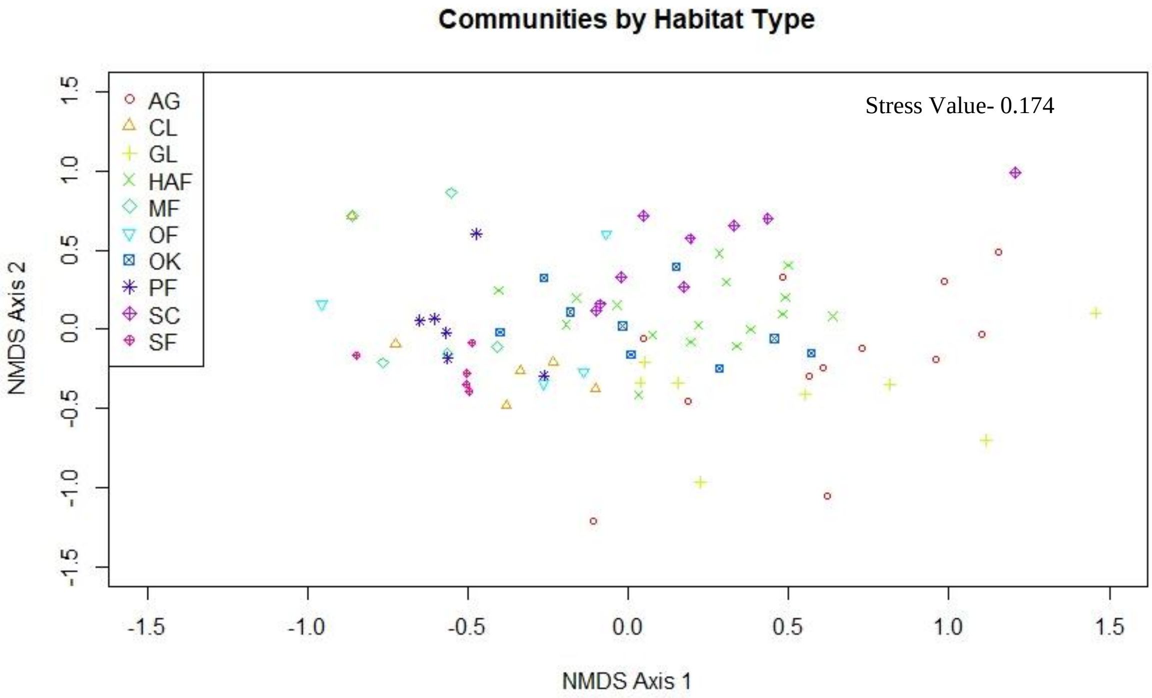


Figure 4. 5 MDS ordination of sampling sites in the KSL, India generated by species composition according to habitat types.

4.5 Discussion

Of the 80 dung beetle species from Uttarakhand listed by Mittal and Jain (2015), 49 species with one new record to state (*Onthophgus hastifer*) were documented in this study. This proportion is very high considering that sampling was confined to selected micro-habitat site. The differences in community composition were mainly due to the sampling approach, as each method appeared to be sampling specific part of the beetle assemblage in a particular stratum.

The high species diversity and abundance of species is observed in Banj Oak forest (OF) harbors maximum species diversity followed by Alpine meadows (BG) and Fir forest (HAF) (Fig 4. 1). *Oniticellus cinctus* was highly abundant followed by *Onthophagus (Colobonthophagus) dama*, *Onitis philemon*, *Liatongus mergacerus*, *Liatongus phanaeoides*, and *Tiniocellus spinipes* in the study area (Figure 4. 3). Hence these species are important contributors in the dung removal in the landscape. Populations of dung beetles are tend to be less diverse in human habitation, this may be because of similar kind of dung availability. Another possible reason for the low diversity in the human habitation is the greater microclimatic variation in temperature, humidity and light intensity. In total, 12 species were singletons (i.e. species with only one individual collected throughout the sampling periods). The high number of rare species in the habitat sites is typical for studies of tropical insect faunas. Moreover, small isolated habitat with high rare species most likely to lose species which are uncommon in the landscape. Mac Arthur (1972) explains how mountains are special case of equilibrium/island paradigm, being isolated systems. Mountain should have high extinction rates and low immigration rates and, therefore the equilibrium species number is lower than lowland communities (Macarthur & Wilson 1967).

The beetle community structure also alters in different habitats comparatively, Banj Oak forest and Alpine meadows exhibit highly diverse assemblages, possibly due to higher structural complexity and heterogeneity. The relatively open and availability of diverse dung pats in these habitats supported the highest number of beetle species. These sites were also rich in soil organic matter which plays crucial role in nesting strategy of the dung beetles.

Importance of Oak forests and alpine meadows are well established in western Himalaya. Oak forests harbors maximum diversity of mammals and other fauna (microorganisms and birds) hence increased availability of dung maintain high diversity of dung beetles. Alpine meadows contributes in mountainous ecosystem by providing noble habitat for many species like the snow leopard (*Uncia uncia*), and the large montane ungulates such as blue sheep (*Pseudois nayur*), Himalayan tahr (*Hemitragus jemlahicus*) and Himalayan musk deer (*Moschus chrysogaster*). Ultimately this lead to high species abundance and diversity of dung beetles in alpine meadows. Proxies of resource availability, particularly mammal species richness correlates with dung beetle species richness. α- diversity, size structure of local assemblages, and metacommunities of dung beetles are shaped by the contemporary distribution and abundance of mammal faunas and their functional traits (Culot et al. 2013; Van Rensburg et al. 1999; Martikainen et al.2000). The pastoralists move from lower altitudes of the KSL to higher alpine regions in monsoon and return back to lower altitude villages with their livestock (sheep, goats, and yak). The forested areas along the routes of transhumant pastoralists provides food resource (dung pats). This results leads to high species diversity in the alpine meadows.

It was interesting to note that the species diversity did not follow unimodal peak in mid-elevation of the landscape. Not decline much in high elevation ranges the reason being the agropastrolism in the alpine meadows in monsoon (Beans, Darma, Gori & Chaudans valley). There is another interesting finding that two species *Onthphagus dama* and *Oniticellus cinctus* are widely distributed up to mid elevation (2500m) while three species in Liatongus genus are most dominant in high elevation (2500m-4000m).

The most abundant species are tunnellers in the study. Only four roller species (*Sisyphus*, *Gymnopleurus* and *Paragymnopleurus*) have been identified from the landscape. Davis & Scholtz (2001) explains that regions with low dung type diversity (small dung types from small-bodied mammals) favoured high proportions of ball rollers (genera & species), and high dung type diversity (range in dung types and sizes from large to small mammals) favoured high proportions of tunnellers. It is also believed that rollers are more superior to tunnellers. Community composition in agricultural and grassland habitat is quite distinctive from other habitat while some of these habitats share similar species composition. The reason being some large bodied dung beetles have movement rage of 2-4 km while other small species just have range of less than 1 km.

Species composition was also significantly different between sites. Since, species diversity of beetles was found to be higher in primary, mixed and alpine meadows where the greatest landscape heterogeneity occurs (interfaces of forest-agriculture landscape and grazing). While habitat degradation leads to conversion of natural or continuous forests into forest patches of different size. Which ultimately reduces total area of habtat. This could lead to creation of subpopulations of species and ecological processes also disturb at different levels. This landscape is also witnessing the anthropogenic pressure and forest fragmentation. This landscape is also witnessing the anthropogenic pressure and forest fragmentation. As all mountains are most susceptible to climate change hence species inhabiting these areas are likely to face the impact of climate change at large scale. Climate change leads to range shift of the species residing the landscape and also possible extinction of taxon. Therefore conservation of natural forests is utmost important to conserve the species. Likewise planning and management strategies should be formulated for further strengthening the species conservation.

Chapter 5

Taxonomic studies on dung beetles

5.1 Introduction

Taxonomy, concerned with the identification and classification of organisms, has been called the oldest, the most limited, and the most inclusive of the biological sciences. It is a useful tool for naming populations of organisms and drawing conclusions as to the morphology, physiology, behavior, distribution, etc. of such populations (Cagle 1955). Application of dung beetles as bioindicator in ecological monitoring to assess the forest degradation, habitat fragmentation, impact of climate change is verified by several studies. Assessment and evaluation of species composition, community structure, diversity and distribution of species have been selected in ecological studies to predict the consequences of climate change, anthropogenic pressure and impact of land use changes. Species reacts to alter environmental factors such as temperature, humidity and rain fall pattern. This correlation of species with variables gives information about the ecosystem and forest heath, which ultimately decoded into policy framework and mitigative measures.

Dung beetles are potential bioindicator used for the estimation of forest health and water quality. It is possible to demonstrate differences in correlations between major environmental influences (climatic zone, altitudinal differences) and major components of diversity (taxon richness, taxon diversity, functional composition) at different taxonomic levels (tribe, genus, species). Taxonomy is a prerequisite for any successful ecological monitoring module. Intra and interspecies divergence is also dependent on the taxonomic interpretation. Identification and description of species faces key challenges such as availability of expertise, limited resources and hyper-diverse taxa. When many species are on the verge of extinction, responsibility of researchers has increased. Need of species identification has coupled with formulating and adopting measures for conservation. Without a robust taxonomic paradigm that is based on science and unconstrained by unnecessary and counterproductive bureaucracy, conservation efforts will ultimately suffer, potentially leading to devastating and irreversible impacts on global biodiversity.

5.2 Methods

Beetles were collected by the various sampling methods *viz*., hand sorting, pitfall trap and light trap as previously discussed (Section 3.8).

5.3 Inventory of dung beetles from KSL, Pithoragarh, Uttarakhand, India

A total of 49 species, 17 genera, six tribes of dung beetles (Scarabaeidae: Scarabaeinae) have been documented from the landscape. Most dominant tribe is Onthophagini with seven genera and 20 species followed by Oniticellini with five genera and eight species, Onitni with five species. Four species remain unidentified. List has been provided in Appendix 5.1.

5.4 Taxonomic accounts

Family Scarabaeidae Latreille, 1802

Diagnostic characters

Very small to giant scarabs, 2.0-50.0 mm in length; shape variable, dorsoventrally convex, mostly elongate oval, robust, sometimes cylindrical, flattened or globular, quadrate; colour variable with or without metallic reflections or metallic colouration; with or without hairs or setae; head weakly deflexed or not deflexed; antennae 10 segmented sometimes 9 or 8 segmented, with 3 to 7 segmented opposable club; club with apical segments nearly glabrous in Melolonthinae, Dynastinae, Rutelinae, and Cetoniinae or with all segments tomentose in Aphodiinae and Scarabaeinae; eyes partially divided by a canthus; clypeus with or without tubercle or horn; labrum usually distinct, produced or not beyond apex of clypeus; mandibles variable, produced or not beyond apex of labrum; maxillae with 4 segmented palpi; labium with 3 segmented palpi; pronotum variable, with or without horns or tubercles; elytra convex or flattened, with or without striae; pygidium concealed by elytra in Aphodiinae and Scarabaeinae or exposed in some Scarabaeinae, Melolonthinae, Dynastinae, Rutelinae, and Cetoniinae; scutellum visible or not, shape triangular or parabolic; legs with coxae transverse or conical; protibiae quadridentate, tridentate, or bidentate, or serrate on outer margin, apex with one spur; meso and meta tibiae slender or robust, apex with 1 or 2 spurs; spurs mesad, adjacent or separated by basal metatarsal segment; tarsi 5-5-5, pro tarsi absent in some Scarabaeinae; claws variable, equal in size or not, simple or toothed; empodium present, extending beyond fifth tarsal segment, with 2-5 setae or with setae absent; abdomen with 6 free sternites; 7 functional abdominal spiracles situated in pleural membrane in Aphodiinae and Scarabaeinae or in pleural membrane, in sternites, and in tergite in Melolonthinae, Dynastinae, Rutelinae, and Cetoniinae; wings well developed.

Subfamily Scarabaeinae Latreille, 1802

Scarabaeïdes Latreille, 1802, 3: 144.

Type genus: *Scarabaeus* Linnaeus, 1758: 345.

Diagnostic characters

Head broad and flat; clypeus expanded, margins rounded, straight, excised, or dentate, covering mouthparts; mandibles lammelliform mostly membranous apically and hard basally; labrum thin and membranous; antennae 8 or 9 segmented with club 3 segmented; scutellum generally invisible sometimes visible; elytra exposing pygidium; 6 visible, fused abdominal sternites; prolegs short; protibiae usually quadridentate, sometimes tridentate; metatibiae generally dilating at apex; mesotibiae with 2 terminal spurs, others with 1 each; protarsi feebly developed, sometimes absent, metatarsi generally flattened and tapering towards extremities; mesocoxae widely separated; phallobase generally longer than parameres, usually cylindrical, with a large basal opening; parameres separate or mostly joined together with membrane, never consolidated into one, generally symmetrical.

Identification key to the tribes of subfamily Scarabaeinae

1. Meso and meta tibiae usually long, slender, more or less curved, apex of which not widened, of almost uniform size; meso and meta femora elongate; tarsal segments not triangular; scutellum visible (Scarabaeini) or not visible (Gymnopleurini or Sisyphini); mesocoxae oblique or parallel; sexual dimorphism not prominent; flat, short and a little arched in shape; rollers ……………………………………………………..…….…………**2**

- Meso and meta tibiae broad, short, triangular, apex of which strongly dilated; meso and meta femora not elongate somewhat broad in middle; scutellum not visible (Coprini and Onthophagini) or visible (Onitini and Oniticellini); sexual dimorphism prominent; mesocoxae parallel; strongly convex and oval, large to small sized; tunneller or dwellers……………….………………………………...…………..**3**

2. Mesocoxae oblique and not widely separated; mesotibiae with one terminal spur; metasternum almost vertical in front; protarsi present or absent; antennae 9 segmented; scutellum visible not visible Scutellum not visible; elytra excised behind shoulder; protarsi present; tarsi long with two tarsal claws; protibiae tridentate …………………...….…………….....**Gymnopleurini Lacordaire, 1856**

- Mesocoxae parallel, widely separated and almost shifted towards lateral margins; mesotibiae with two terminal spurs; metasternum flat in front; protarsi present; antennae 8 segmented; scutellum not visible……………….………..………..**Sisyphini Mulsant, 1842**

3. Second segment of labial palpi smaller than first, third always distinct……….………………….…………………………………..**4**

- Second segment of labial palpi longer than first, third very small sometimes scarcely visible or absent………………………………………..…….……………..**5**

4. Very large sized; antennae 9 segmented; clypeal margin variable never quadridentate; elytra not excised behind shoulders not exposing epipleurae; outer side of meso and meta tarsal segments with a pointed

sometimes thorn like process at end…………………..…..……………..……….**Coprini Leach, 1815**

5. Antennae 8 segmented; pronotum without basal impressions; scutellum small and visible; protarsi present; protibial spur movable…………………….………………..**Oniticellini Kolbe, 1905**

- Antennae 9 segmented; pronotum with or without basal impressions; protarsi present or absent; protibial spur movable or immovable……….………………………………………..….…….**.6**

6. Pronotum with two basal impressions; pro tarsi absent in both sexes; scutellum visible; protibiae elongate; terminal spurs of protibiae immovable; sexual dimorphism not prominent ………………….…………………………...**Onitini Laporte, 1840**

- Pronotum without any basal impressions; pro tarsi present in both sexes; scutellum not visible; protibiae not elongate rather broad; terminal spur of protibia movable; sexual dimorphism prominent…….……………………..**Onthophagini Burmeister, 1846**

Tribe Gymnopleurini Lacordaire, 1856

Gymnopleurides Lacordaire 1856, III: 72.

Type genus: *Gymnopleurus* Illiger, 1803: 199.

Diagnostic characters

Flat, short and a little arched; size ranging from 10.5 mm to 17.5 mm in length; metallic green or blue, even violet or non metallic shiny black; rollers; lateral edge of each elytron exposes underlying pleural sclerites; protibiae tridentate, each with one terminal spur; protarsi present; meso and meta femora elongate; meso and meta tibiae usually long, slender, more or less curved, apex of which not widened and of almost uniform size; mesotibiae with one terminal spur; tarsi long with 2 claws not triangular; mesocoxae oblique not widely separated; clypeus bi or quadridentate; antennae 9 segmented; pronotum punctate or granulate with or without two minute slits near base, with or without shining spots; scutellum not visible; metasternum almost vertical in front; sexual dimorphism very little and dimorphic characters lie on on protibial structure

Identification key to the genera of Gymnopleurini

1. Lateral sides of abdomen not carinate at base……………………......... ……………………………………..………***Gymnopleurus*** **Illiger, 1803**
2. Lateral sides of abdomen carinate at ……………………………….….. base……………….……………..…...***Paragymnopleurus*** **Shipp, 1897**

Genus *Gymnopleurus* Illiger, 1803

Gymnopleurus Illiger, 1803, II: 199 - Lacordaire, 1856, III: 72, 73 - Garreta, 1914, 83 (1): 51, 55 - Janssens, 1940a, 2 (18): 40 - Arrow, 1931, III: 46 - Balthasar, 1935b, 115: 38 - Balthasar, 1963a, I: 177 - Bezdek, 2006b, 3: 154.
Spinigymnopleurus, Shipp, 1897, XXX: 166.
Type species: *Scarabaeus flagellatus* Fabricius, 1787.

Diagnostic characters

Broadly oval, convex and depressed; antennae 9 segmented with 3rd joint as long as 4th and 5th together, 6th one extremely short; clypeus bi or quadridentate at front; an oblique suture separates genae from clypeus; vertex with a sharp rounded carina; pronotum moderately convex, strongly punctate or granular with shining spots, smooth or hairy, front angles acutely produced, lateral sides rounded and carinate; lateral side of elytra deeply excised behind shoulder exposing metasternal epimera; elytra finely striate, sometimes hairy with shining spots or sometimes smooth and strongly confluently punctate; protibiae tridentate, remaining surface strongly serrate; profemora hollowed at anteriorly bearing a sharp a tooth beyond middle and sharply carinate, tooth sometimes absent; outer and inner edge of meta and meso tibiae serrated or toothed.

Gymnopleurus cyaneus Fabricius, 1798

(Plate No. 3: Fig. 1 a, b)

Copris cyaneus Fabricius, 1798: 34.

Gymnopleurus cyaneus, MacLeay, 1821, I, 2: 515 - Arrow, 1931, III: 49, pl. 3, f. 6 - Janssens, 1940a, 2 (18): 53, 66, pl. II, fig. 9 - Bezdek, 2006b, 3: 154.

Gymnopleurus impressus, Laporte, 1840, II: 73.

Gymnopleurus indicus, Laporte, 1840, II: 73 - Gillet, 1911, LV: 314.

Gymnopleurus (Gymnopleurus) cyaneus, Balthasar, 1963a, I: 207.

Diagnostic characters

Colour: bright metallic green; antennal club light black; tarsi dark brown; dorsally devoid of hairs while ventrally with small sparse hairs. Shape: oval and convex. Head: clypeus rugose, quadridentate at front; frons shining and deeply punctate; an oblique suture separates genae from clypeus; genae rugose, not rounded. Pronotum: sparsely but strongly punctate, slightly rugose at front margin; a strong pit present at lateral side in middle; a small median groove present in middle near base; front angles acutely produced; lateral sides rounded and carinate; base rounded and margined. Elytra: lateral side deeply excised behind shoulder exposing metasternal epimera; each elytron entirely confluently punctate. Legs: protibiae tridentate, remaining surface strongly serrate; profemora hollowed anteriorly bearing a sharp a tooth beyond middle, sharply carinate; outer and inner edge of metatibiae serrate while of mesotibiae toothed. Pygidium: angular in shape with a carina in middle and little hollowed on each side. Venter: metasternum vertical in front and a little produced, smooth in middle, a little closely at front, rugosely punctate laterally.

External male genitalia (Plate No. 3: Fig. 1 b)

Phallobase longer than parameres; parameres broad at base and irregularly tapered distally with tips pointed.

Genus *Paragymnopleurus* Shipp, 1897

Paragymnopleurus Shipp, 1897, XXX: 166 - Garreta, 1914: 52 - Janssens, 1940a, 2 (18):
15 - Paulian, 1945, III: 51 - Bezdek, 2006b, 3: 155.
Gymnopleurus subgenus *Paragymnopleurus,* Balthasar, 1963a, I: 177.
Type species: *Scarabaeus sinuatus* Olivier, 1789.

Diagnostic characters

Piceous or coppery black; broad and slender; clypeus bidentate, an oblique suture separates lateral side of clypeus from rounded genae; pronotum finely and closely punctate, front angles acute and pointed, lateral angles strongly angulate or rounded in middle, lateral side with a single carina, hind angles a little elevated and pointed; elytra finely striate with 8 striae, intervals coriaceous; sides of abdomen sharply carinate at front; pygidium minutely and sparsely punctuate; protibiae tridentate,remaining surface strongly serrated; profemur hollowed at anterior with a minute tooth beyond middle, its outer edge strongly carinate; meso and meta tibiae feebly serrated on outer edge while not serrated on its inner side but with fine hairs; metasternum feebly punctate in middle with a smooth median line, vertical in front.

Paragymnopleurus sinuatus assamensis Waterhouse, 1890

(Plate No. 3: Fig. 2 a, b)

Gymnopleurus assamensis Waterhouse, 1890a, (6), V: 411.

Scarabaeus sinuatus, Olivier, 1789, I: 160, pl. 160, fig. 189.

Gymnopleurus sinuatus, Boucomont, 1921, 4: 3 - Arrow, 1931, III: 63.

Gymnopleurus sinuatus var. *assamensis,* Arrow, 1931, III: 63.

Paragymnopleurus sinuatus, Shipp, 1897, XXX: 166 - Janssens, 1940a, 2 (18): 17, 20, pl.I, fig. 1.

Gymnopleurus (Paragymnopleurus) sinuatus, Garreta, 1914: 52 - Balthasar, 1963a, I: 218, pl. 10, fig. 2.

Paragymnopleurus sinuatus ssp. *assamensis,* Bezdek, 2006b, 3: 155.

Diagnostic characters

Colour: piceous or coppery black; mouthparts and antennal club bright yellow; devoid of hairs except dense hairs on lateral sides of metasternum. Shape: broad and slender. Head: minutely granular; clypeus bidentate; an oblique carinate suture separates lateral side of clypeus from genae; ocular lobes rounded. Pronotum: finely and closely punctate; front angles acute and pointed; lateral angles strongly angulate in middle and lateral side with a carina; hind angles a little elevated and pointed; base flat; a very small smooth pit present in middle on each lateral side. Elytra: finely striate; intervals coriaceous; sides of abdomen sharply carinate at front. Pygidium: minutely and sparsely punctate. Legs: protibiae tridentate and remaining surface strongly serrate; profemora hollowed at anterior with a minute tooth beyond middle and its outer edge strongly carinate; meso and meta tibiae feebly serrate on outer edge while not serrate on its inner side but with fine hairs. Venter: prosternum a little elevated in middle; propleuron smooth with very sparse hairs; metasternum feebly punctate in middle with a smooth median line, vertical in front, lateral sides with dense yellow hairs and coriaceous, mesocoxae not parallel; mesosternum narrow in middle, granular with yellow hairs; lateral side of metasternum, metepisternum and mesepimeron granular and closely hairy.

External male genitalia (Plate No. 3: Fig. 2 b)

Phallobase longer than parameres; parameres broad at base, tapered distally with a cup shaped cavity sub apically on dorsal side with tips blunt.

Tribe Sisyphini Mulsant, 1842

Sisyphaires Mulsant, 1842: 41.

Type genus: *Sisyphus* Latreille, 1807: 79.

Diagnostic characters

Small sized; spider like; about 5 to 8 mm in length, strongly convex; dorsally clothed with short hooked setae; pronotum with anterior angles hollowed at ventral surface, flattened laterally with dorsal edge of hollow sharply defined by a distinct carina; protibiae short, stout and tridentate; teeth acute; meso and meta legs extremely long; meso and meta tarsi slender, former distinctly longer than mesotibiae; mesocoxae parallel; sexual dimorphism relatively evident with male distinguished from female by presence of teeth on meso and meta femora or often meso and meta tibiae.

Genus *Sisyphus* Latreille, 1807

Sisyphus Latreille, 1807, II: 79; Arrow, 1931, III: 67 - Balthasar, 1963a, I: 233 - Bezdek, 2006a, 3: 178.

Type species: *Scarabaeus schaefferi* Linnaeus, 1758.

Diagnostic characters

Subglobose, compressed laterally, with very long and loosely articulated posterior legs; dorsally clothed with short, erect, hooked setae; ventrally smooth; protibiae tridentate, serrate at inner edge; meso and meta legs very long and slender; mesocoxae parallel, far apart; mesofemora slender at base, thickened before end; mesotibiae curved, tarsi longer than it; metatibiae very long and slender, serrate at inner edge, tarsi long, basal joint of meso and meta tarsi as long as 2nd and 3^{rd} together; clypeus completely fused with genae with 2 or 4 teeth at its front margin; antennae 8 segmented, 3rd joint slightly elongate, 4th and 5th very short; pronotum strongly compressed behind, hollowed at ventral surface in front angles; scutellum not visible; elytra very short, narrowing rapidly from shoulders to apices; mesosternum broad, flat, separated by a straight suture from metasternum; metasternum broad and flat between mesocoxae, generally hollowed behind; pygidium long and narrow.

Identification key to the species of Genus *Sisyphus*

1. Metafemur gradually dilated.. …………………………***Sisyphus (Sisyphus) longipes*** **(Olivier, 1789)**
2. Metafemur abruptly dilated... …………………………….***Sisyphus (Sisyphus) neglectus*** **Gory, 1833**

***Sisyphus (Sisyphus) longipes* (Olivier, 1789)**

(Plate No. 3: Fig. 3 a, b)

Scarabaeus longipes Olivier, 1789, I, 3: 164, pl. 19, fig. 177.

Scarabaeus minutus, Fabricius, 1792, I: 70.

Copris helwigi, Fabricius, 1798: 35.

Sisyphus longipes, Arrow, 1927, (9), XIX: 457 - Arrow, 1931, III: 71 - Haff, 1955, 6 (1): 347, 355.

Sisyphus (Sisyphus) longipes, Balthasar, 1963a, I: 239

Diagnostic characters

Colour: piceous and shining; dorsally with minute and inconspicuous erect, reddish setae, fairly close upon pronotum; very sparse upon head, elytra and ventral surface. Shape: oval and highly convex. Head: strongly punctate; clypeus produced into sharp widely separated teeth. Pronotum: finely punctate; moderately closely in front, sparsely behind with a posterior groove in middle; front angles acute; lateral angles strongly angulate before middle; hind angles on lateral side flattened. Elytra: not longer than their conjoint width; intervals flat. Pygidium: with large, shallow round pits. Legs: protibiae tridentate, teeth very close, remaining upper surface strongly serrate; spur long and pointed; meso and meta femora with slender part basal part and swollen terminal part; trochanter of metafemur prominent. Venter: metasternum divided by a curved suture from mesosternum, finely and sparsely punctate with a round depression.

External male genitalia (Plate No. 3: Fig. 3 b)

Phallobase a little shorter than parameres; parameres tapered with sides almost parallel, and apical part partially angled, with tips pointed, and median sclerotized part broadly and strongly curved inward on dorsal side.

***Sisyphus (Sisyphus) neglectus* Gory, 1833**

(Plate No. 3: Fig. 4 a, b)

Sisyphus neglectus Gory, 1833: 14 - Arrow, 1927, (9), XIX: 460 - Arrow, 1931, III: 73.

Sisyphus denticrus, Fairmaire, 1886, (6) VI: 320.

Sisyphus (Sisyphus) neglectus, Balthasar, 1963a, I: 242 - Bezdek, 2006a, 3: 178

Diagnostic characters

Colour: piceous and opaque; legs and metasternum shining; dorsally closely clothed with yellow, short, hooked setae while setae on ventral surface fairly sparse; mouthparts red; antennal club yellow. Shape: highly convex. Head: closely setose, clypeus quadridentate, two inner teeth widely separated, outer one very blunt and feeble; genae separated by an oblique carina from clypeal margin; a triangular clypeofrontal carina present, which joins with genal suture; genae slightly round; vertex with semicircular carina. Pronotum: wider than long; closely punctate with a deep posterior median groove; front angles acute; lateral angles strongly angulate before middle; base flat. Elytra: finely striate; striae and flat intervals closely punctate. Legs: protibiae tridentate, teeth very close, remaining upper surface strongly serrate, spur long and pointed; profemur with two carinas, lower one serrated; mesofemur slender at base but broad at end; mesotibiae not serrated; meta legs very long and slender; metafemur slender at base and basal half forming a long foot stalk; trochanter of metafemur with a sharp tooth in middle; metatibiae serrated on both lower and upper surface. Venter: metasternum finely punctate with a deep depression in middle at posterior region; lateral side of metasternum, mesosternum, metepisternum, and mesepimeron coarsely punctate.

External male genitalia (Plate No. 3: Fig. 4 b)

Phallobase a little shorter than parameres; parameres broad with sides almost parallel, and apical part sharply tapered, and median sclerotized part broadly and feebly curved inward on dorsal side**.**

Tribe Coprini Leach, 1815

Coprides Leach, 1815, 9: 96.
Coptodactylini, Janssens, 1946, 22 (12): 10.
Type genus: *Copris* Geoffroy, 1762: 59.

Diagnostic characters

Strongly convex and oval, large sized; generally black; tunneller; meso and meta tibiae broad, short, triangular in shape, apex of which strongly dilated; mesocoxae parallel; meso and meta femora not elongate somewhat broad in middle; head and pronotum always with horn or tubercles in males; 2nd segment of labial palp smaller than 1st, 3rd always distinct; antennae 9 segmented; scutellum not visible; sexual dimorphism prominent; elytra with one or two lateral carina

Identification key to the genera of tribe Coprini

1. Elytra with two lateral carinas, 1st posterior one entire, reaching up to posterior region of elytra while 2nd anterior one more or less shortened; 7 elytral striae…………..…………. ***Catharsius* Hope 1837**
- Elytra with one lateral carina ……………………………………………………………..……..**2**
2. Pronotum with sharply defined anterior declivity, dorsally closely or very feebly or unequally or not at all punctate, with or without smooth median longitudinal line; pronotum deeply excavated in front margin with well developed tubercles…………………***Copris* Geoffroy, 1762**
- Pronotum without sharply defined anterior declivity, dorsally strongly and closely punctate, with or without smooth median line; elytral intervals closely, densely and strongly punctate sometimes finely punctate, shoulder of each elytron carinate………..……………………..….. ***Paracopris* Balthasar, 1939**

Genus *Catharsius* Hope 1837

Catharsius Hope, 1837, 1: 21 - Arrow, 1931, III: 92 - Balthasar, 1963a, 1: 304 - Löbl,
Krell, and Král, 2006b, 3: 151.

Type species: *Scarabaeus molossus* Linnaeus, 1758.

Diagnostic characters

Broadly oval, highly convex; dorsally devoid of hairs while ventral surface with yellow hairs on metepisternum, legs, mouthparts and antennae; antennae 9 segmented; antennal club pubescent; clypeus semicircular in front, feebly excised in middle, closely transversely rugose; ocular lobes separated from clypeus by a slant carinate suture; pronotum granular, lateral angles with a single carina; elytra finely striate with 7 striae, lateral sides with two carinas;

scutellum not visible; metasternum angular or straight in front, hairy or without hairs; protibiae tridentate; meso and meta tibiae broad at base; tarsal segments truncate and diminish in size from first to last.

Identification key to the species of Genus *Catharsius*

1. Pronotum not vertical in front in both sexes; males with two widely separated tubercles in middle of pronotum while females without any tubercle or carina; elytra shining; in males, head with a long slender, pointed and curved horn reaching up to middle of pronotum……….…………..…***Catharsius pithecius* (Fabricius, 1775)**

- Pronotum vertical in front and with a carina in middle in both sexes; elytra opaque; in males, head with a pointed horn, broad at base, not reaching up to middle of pronotum .………………..……………………………...……………………**2**

2. In males, frons with a straight horn in middle, broad at base pointed at end, pronotum vertical in front with a strong convex carina in middle whose end produced into sharp and pointed processes; in females, pronotal carina nearly straight, area adjoining each eye smooth………………………………………………………………… ……..……………..…………..***Catharsius molossus* (Linnaeus, 1758)**

- In males, frons with a slightly sinuated horn, broad at base and pointed at end, placed a little close to clypeus; pronotum vertical in front and with a straight carina; in females pronotal carina convex in middle and sinuate, area adjoining each eye closely granular……………...……………***Catharsius sagax* (Quenselt, 1806)**

Catharsius pithecius (Fabricius, 1775)

(Plate No. 4: Fig. 5 a, b)

Scarabaeus pithecius Fabricius, 1775: 21.

Scarabaeus sabaeus, Fabricius, 1781, I: 23.

Scarabaeus nanus, Fabricius, 1792, I: 42.

Copris sinensis, Hope, 1842: 62.

Copris cribricollis, Walker, 1858, (3) II: 208.

Catharsius pithecius, Boucomont and Gillet, 1921, IV: 9 - Arrow, 1931, III: 100, pl.7, fig.
1, 2 - Balthasar, 1935b, 115: 64 - Löbl, Krell, and Král, 2006b, 3: 151

Catharsius (Catharsius) pithecius, Balthasar, 1963a, I: 312, pl. 15, fig. 2.

Diagnostic characters

Colour: piceous and opaque; dorsally devoid of hairs; ventrally with sparse yellow hairs on metepisternum, legs, mouthparts and antennae; antennal club piceous. Shape: oval and very convex. Head: clypeus semicircular in front, feebly excised in middle, closely transversely rugose; genae angulate. Pronotum: closely granular with some shining and smooth area in middle at base; front angles rounded. Elytra: finely striate; intervals flat, finely and sparsely punctate. Pygidium: finely and closely punctate. Legs: protibiae tridentate. Venter: metasternum angular in front, finely punctate in middle with a smooth median line at lateral side more closely punctate with few yellow hairs.

External male genitalia (Plate No. 4: Fig. 5 b)

Phallobase almost equal in length as parameres; parameres broad, tapered distally and slightly curved ventrally, with tips bluntly pointed.

Catharsius molossus (Linnaeus, 1758)

(Plate No. 4: Fig. 6 a, b)

Scarabaeus molossus Linnaeus, 1758, X: 347.

Scarabaeus abbreviatus, Herbst, 1789, II: 53.

Scarabaeus berbiceus, Herbst, 1789, II: 228.

Scarabaeus janus, Olivier, 1789, I: 101.

Scarabaeus ursus, Fabricius, 1801, I: 43.

Catharsius timorensis, Lansberge, 1879, CXLVIII: 148.

Scarabaeus dayacus, Lansberge, 1886, XXIX: 6.

Catharsius kangeanus, Paulian, 1936, 15: 395.

Catharsius molossus, Harold, 1877, 10: 44 - Boucomont and Gillet, 1921, IV: 8 - Arrow, 1931, III: 94 pl.8, fig. 6, 7 - Balthasar, 1935b, 115: 65 - Paulian, 1945, III: 69 - Löbl, Krell, and Král, 2006b, 3: 151 - Krajcik, 2006: 35.

Catharsius (Catharsius) molossus, Balthasar, 1963a, I: 307, pl. 14, fig. 1

Diagnostic characters

Colour: piceous and shining; dorsally devoid of hairs; ventral surface with long, dense and yellow hairs. Head: transversely rugose; clypeus rounded at front and feeble excised; genae rounded, closely granular with area adjoining each eye smooth. Pronotum: closely and universally granular; front angles truncate; lateral angles rounded; base flat. Elytra: finely striate; intervals flat and coriaceous. Pygidium: coriaceous, granular at sides. Venter: metasternum angular in front, hairy and closely punctate, smooth in middle with a strong and smooth median line, lateral side very closely and densely hairy. Legs: protibiae tridentate**.**

External male genitalia (Plate No. 4: Fig. 6 b)

Phallobase slightly shorter than parameres; parameres broad at base and slightly tapered distally, with a sinuation on dorsal side and tips blunt.

***Catharsius sagax* (Quenselt, 1806)**

(Plate No. 4: Fig. 7 a, b)

Copris sagax Quensel, 1806, I: 43.

Catharsius sagax, Boucomont and Gillet, 1921, IV: 8 - Arrow, 1931, III: 96, pl. 8, fig. 3 - Balthasar, 1935b, 115: 65 - Löbl, Krell, and Král, 2006b, 3: 153 - Krajcik, 2006: 36.

Catharsius (Catharsius) sagax, Balthasar, 1963a, I: 309**.**

Diagnostic characters

Colour: piceous and shining; dorsally devoid of hairs; ventral surface with long, dense and yellow hairs. Head: transversely rugose, clypeus rounded at front; genae closely granular and angulate. Pronotum: closely and universally granular; front angles truncate; lateral angles rounded; base flat. Elytra: finely striate; intervals flat and coriaceous. Pygidium: finely granular. Legs: protibiae tridentate. Venter: metasternum angular in front and hairy, smooth in middle with few granules and a smooth median line, lateral side very closely and densely hairy.

External male genitalia (Plate No. 4: Fig. 7 b)

Phallobase a little shorter than parameres; parameres broad at base and tapered distally with apical part slightly curved ventrally, and tips feebly pointed slightly hooked inward.

Genus *Copris* Geoffroy, 1762

Copris Geoffroy, 1762, I: 87 - Arrow, 1931, III: 102 - Balthasar, 1963a, I: 317 - Löbl, Krell, and Král, 2006b, 3: 151.

Type species: *Scarabaeus lunaris* Linnaeus, 1758.

Diagnostic characters

Broadly oval and convex; black and shining; clypeus smooth or rugose or punctate in front and strongly bilobed; in males, frons with a long pointed and slender horn, reaching almost middle of pronotum with small teeth near base; pronotum with sharply defined anterior declivity, dorsally closely or very feebly or unequally or not at all punctate, with or without smooth median longitudinal line; pronotum deeply excavated in front margin with well developed tubercles; elytra with 8 striae and with one carina on each lateral side, intervals finely, punctate or entirely smooth; protibiae tri or quadridentate

Identification key to the species of Genus *Copris*

1. Pronotum almost smooth, head strongly notched; elytra acutely striate ……………………………………….... ***Copris repertus* Walker, 1858**
2. Pronotum less smooth, head feebly notched, elytra frailly striate………………………………….***Copris sarpedon* Harold, 1868**

Copris repertus Walker, 1858

(Plate No. 4: Fig. 8)

Copris repertus Walker, 1858, (3) II: 208 - Arrow, 1931, III: 116, pl. 9, fig. 7, 8 - Krajcik, 2006: 44.

Copris claudius, Harold, 1877, X: 48.

Copris (Copris) repertus, Balthasar, 1963a, I: 346 - Löbl, Krell, and Král, 2006b, 3: 152.

Diagnostic characters

Colour: Black, shining with antennae, mouthparts, bristles upon legs and ventral surface reddish. Shape: broadly oval and highly convex. Head: clypeus semicircular at front margin, deeply notched in middle with a slight lobe, surface rugose; genae rugosely punctate. Pronotum: very shining with a strong longitudinal groove in middle; sides strongly rounded; front angles truncate; hind angles almost obsolete. Elytra: autely striate, except at base and apex; intervals flat, very minutely and inconspicuously punctate. Venter: metasternum smooth in middle with sides moderately closely punctate and sparsely setose. Legs: protibiae quadridentate.

Copris sarpedon Harold, 1868

(Plate No. 5: Fig. 9)

Copris sexdentata Redtenbacher, 1848, (2) IV:520.
Copris sarpedon Harold, 1868 IV: 104-Arrow, 1931, III: 110, pl. 9, fig. 1, 2.
Copris pompilius Waterhouse, 1875, 75.

Diagnostic characters

Colour: Black, shining with antennae, mouthparts, bristles upon legs and ventral surface blackish. Shape: broadly oval and highly convex. Pronotum: very shining with a strong longitudinal groove in middle; Elytra: lightly striate, except at base and apex; Venter: metasternum smooth in middle with a pit in middle, sides strongly distantly punctate. Legs: protibiae quadridentate.

Genus *Paracopris* Balthasar, 1939

Copris subgenus *Paracopris* Balthasar, 1939, XXV: 2 - Balthasar, 1963a, I: 317.

Paracopris, Löbl, Krell, and Král, 2006b, 3: 153.

Type species: *Copris punctulatus* Wiedemann, 1823.

Diagnostic characters

Flat, elongate and slightly convex; black, chocolate brown or grey; opaque or shining; clypeus smooth in front, strongly bidentate or with only one median tooth; in males, frons with horn of different shapes; vertex either hollowed or flat; posterior region of head with a yellow membrane attaching to pronotum; pronotum without sharply defined anterior declivity, dorsally strongly and closely punctate, with or without smooth median lines; elytral intervals closely, densely or strongly punctate sometimes finely punctate; shoulder of each elytron carinate; legs slender; protibiae quadridentate; meso and meta tibiae trilobed at end; meso and meta tarsi diminish in size.

Identification key to the species of Genus *Paracopris* Balthasar, 1939

1. Elytra intervals finely but sparsely punctate ……………………...........***Copris (Paracopris) excisus*** **Waterhouse, 1891**
2. Elytra intervals finely and closely punctate or entirely smooth……………......................***Copris (Paracopris) surdus*** **Arrow, 1931**

Copris (Paracopris) excisus Waterhouse, 1891

(Plate No. 5: Fig. 10)

Copris excisus Waterhouse, 1891, 16, VII: 521- Arrow, 1931, III: 125

Diagnostic characters

Colour: black; head, ventral surface and legs shining; pronotum and elytra opaque; dorsally devoid of hairs; a fringe of yellow hairs present on sides of head and pronotum; legs hairy; antennal club yellow; mouthparts black. Shape: elongate oval not very convex. Head: clypeus smooth in front and strongly bidentate; Pronotum: finely and evenly punctate; a deep impression present on each lateral side near middle. Elytra: finely striate; intervals slightly convex, finely but not closely punctate. Pygidium: strongly and closely punctate. Legs: protibiae quadridentate; meso and meta femora sparsely punctate. Venter: prosternum strongly not closely punctate; metasternum is very smooth in middle with few punctures at front, lateral sides sparingly and fairly strongly punctured.

Copris (Paracopris) surdus Arrow, 1931

(Plate No. 5: Fig. 11 a, b)

Copris surdus Arrow, 1931, III: 132 - Krajcik, 2006: 45.
Copris (Paracopris) surdus, Balthasar, 1963a, I: 374.
Paracopris surdus, Löbl, Krell, and Král, 2006b, 3: 153.

Diagnostic characters

Colour: black sometimes brown; head, ventral surface and legs shining; pronotum and elytra opaque; dorsally devoid of hairs; a fringe of yellow hairs present on sides of head and pronotum; legs hairy; antennal club yellow; mouthparts black. Shape: flat and elongate. Head: clypeus smooth in front and strongly bidentate; genae separated by clypeus by a little curved carina; genae angular and closely punctate; vertex with a slight deep depression in middle. Pronotum: finely and closely punctate; front angles truncate; lateral angles slightly rounded; base flat and margined; a deep impression present on each lateral side near middle. Elytra: finely striate; intervals flat, closely and strongly punctate. Pygidium: strongly and closely punctate. Legs: protibiae quadridentate; profemur with a strong carina, closely punctate at ventral surface; meso and meta femora finely punctate; meso and meta tibiae trilobed at end. Venter: prosternum strongly not closely punctate; mesosternum densely rugopunctate separated by a triangular suture from metasternum; metasternum smooth in middle with a median longitudinal groove and few punctures at front, lateral sides closely punctate; metepisternum and mesepimeron closely punctate.

External male genitalia (Plate No. 5: Fig. 11 b)

Phallobase equal in length as parameres; parameres flat with tips blunt and slightly curved at lower surface.

Tribe Oniticellini Kolbe, 1905

Oniticellini Kolbe 1905, 8: 547.

Type genus: *Oniticellus* Dejean, 1821: 53.

Diagnostic characters

Elongate usually quasi rectangular but occasionally tapering posteriorly, with a slightly flattened, square appearance sometimes convex and oval; comparatively smaller sized; dwellers; antennae 8 segmented; scutellum small and visible; meso and meta tibiae broad, short, triangular, apex of which strongly dilated; meso and meta femora not elongate somewhat broader in middle; sexual dimorphism prominent; mesocoxae parallel; 2nd segment of labial palpi longer than first, 3rd very small sometimes scarcely visible or absent; elytra with one lateral carina; pronotum without basal impressions; protarsi present; protibial spur movable; species separation based on sculpturing and/or punctation of head, pronotal disc and/or elytra.

Identification key to the subtribes of Oniticellini

1. Base of pygidium margined or transversely carinate at base; dorsal surface covered with small thick setae; elytra uniformly colored not spotted………………………..…**Drepanocerina van Lansberge, 1875**
2. Base of pygidium neither margined nor carinate at base; dorsal surface sparsely covered with small simple hairs; elytra entirely uniformly colored or with some spots………….………**Oniticellina Kolbe, 1905**

Subtribe Drepanocerina van Lansberge, 1875

Drépanocérides van Lansberge, 1875, 18: 14.

Type genus: *Drepanocerus* Kirby, 1828: 521.

Diagnostic characters

Base of pygidium margined or transversely carinate at base; dorsal surface covered with small thick setae; elytra uniformly colored not spotted

Tibiodrepanus setosus (Wiedemann, 1823)

(Plate No. 5: Fig. 12 a, b)

Copris setosa Wiedemann, 1823, II, 1: 19.

Ixodina setosa, Wiedemann, 1823, II, 1: 19.

Drepanocerus setosus, Arrow, 1931, III: 381.

Tibiodrepanus setosus, Krikken, 2009, 4: 16, 21 - Barbero et al., 2011, 2923: 36.

Diagnostic characters

Colour: black, with antennae and tarsi reddish, and clothed with grey or yellow scale like setae. Shape: elongate, a little depressed. Head: narrow, unevenly and unequally punctate, with sides nearly straight and parallel behind; clypeus bidentate, deeply impressed between teeth. Pronotum: covered with large shallow pits. Elytra: opaque, broadly but very shallowly striate, with a nearly straight setose ridge upon anterior half of 3rd interval, an entire bisinuate setose ridge upon 5th interval, and one upon 7^{th} interrupted behind shoulder. Pygidium: opaque and setose, hollowed at base and apex and bears a transverse elevation in middle and a longitudinal carina upon anterior half. Venter: metasternum densely and shallowly pitted, coarsely at sides and more finely in middle. Legs: protibiae broad bears 3 short blunt lateral teeth and a sharper one upon straight front margin.

External male genitalia (Plate No. 5: Fig. 12 b)

Parameres very small sized, bent laterally with tips having three pointed tubercles at end.

Subtribe Oniticellina Kolbe, 1905

Oniticellini Kolbe 1905, 8: 547.

Type genus: *Oniticellus* Dejean, 1821: 53.

Diagnostic characters

Base of pygidium neither margined nor carinate at base; dorsal surface sparsely covered with small simple hairs; elytra entirely uniformly colored or with spots**.**

Identification key to the genera Subtribe Oniticellina

1. Black or dark brown, head with two or more carinas; pronotum sparsely or closely punctate with dark shining spots; clypeus straight in front…………………….…………………….***Euoniticellus* Janssens, 1953**

- Head without any carina; pronotum entirely smooth or rugosely punctate without any shining spot; clypeus feebly or strongly excised in middle……..………..**2**

2. Black and shining; devoid of hairs on dorsal and ventral surface; pronotum and head smooth; a yellowish border along sides of elytra from shoulder to posterior region meeting at sutural line …………………………………..………..….***Oniticellus* Dejean, 1821**

- Body brownish, devoid of hairs on dorsal and ventral surface; pronotum and head smooth; small scutellum………………………..…………***Liatongus* Reitter, 1893**

3. Dark brown and opaque; closely clothed with dense hairs on both dorsal and ventral surface; pronotum closely rugosely punctate; ………………………………………..***Tiniocellus* Peringuey, 1900**

Genus *Euoniticellus* Janssens, 1953

Euoniticellus Janssens, 1953, 11: 41 - Bezdek and Krell, 2006a, 3: 156.
Oniticellus subgenus *Euoniticellus*, Balthasar, 1963b, II: 70, 72.
Type species: *Scarabaeus fulvus* Goeza, 1777.

Diagnostic characters

Testaceous with dark metallic smooth spots upon head, pronotum, elytra and pygidium; whole body more or less hairy; head carinate sometimes with a horn in male, clypeus straight in front but laterally sinuous, ocular lobes bluntly produced, vertex more or less raised; frons a little hollowed in middle; pronotum convex, finely or closely punctate with a short deep median groove in middle; elytra with long yellow hairs at posterior; intervals finely punctate; pygidium impressed at apex, finely and sparsely punctate with a smooth median spot in middle; metasternum shining more or less punctate.

Identification key to the species of Genus *Euoniticellus*

1. Pronotum sparsely punctate.…***Euoniticellus pallipes*** **(Fabricus, 1781)**
2. Pronotum closely punctate...........***Euoniticellus pallens*** **(Olivier, 1789)**

Euoniticellus pallipes (Fabricus, 1781)

(Plate No. 5: Fig. 13)

Scarabaeus pallipes Fabricius, 1781, VIII: 33 - Fabricius, 1792, I: 68.
Oniticellus subdeletus, Mulsant, 1842: 96.
Oniticellus nitidicollis, Arrow, 1908, (8), 1: 179.
Oniticellus verticornis, Harold, 1870, VI: 106.
Oniticellus pallipes, Mulsant, 1842: 96 - Costa, 1853: 25, pl. 15, fig. 2 - Arrow, 1931, III:
375, fig. 52 - Balthasar, 1935b, 115, (1): 102 - Paulian, 1941, 38: 64.
Oniticellus (Euoniticellus) pallipes, Balthasar, 1963b, II: 74, pl. 10 fig 3.

Euoniticellus pallipes, Janssens, 1953, 11: 55, fig. 53, 54 - Bezdek and Krell, 2006a, 3:
156 - Krajcik, 2006: 61.

Diagnostic characters

Colour: testaceous; pronotum and head with slightly metallic green suffusion; dorsum and pygidium sparsely hairy; elytra with long yellow hairs at posterior region; venter, legs and mouthparts sparsely hairy; antennal club light yellow; tarsi slightly metallic. Shape: parallel sided and elongate. Head: clypeus excised in middle; genae bluntly produced. Pronotum: feebly and sparsely punctate; a little coarsely punctate in middle; posterior region at base with a short a median groove; front angles blunt and rectangular; lateral sides rounded; base angulate; one spot at front in middle; another one on each side; two spots in middle; two near base in middle; two spots on each lateral side, one a little upper middle and another near lateral fovea. Elytra: lightly striate; 1st, 3rd, and 5th intervals little convex, others flat; intervals finely punctate; a short triangular scutellum present. Pygidium: opaque, impressed at apex, finely and sparingly punctate. Legs: protibiae quadridentate. Venter: metasternum finely punctate with a very fine median line, at lateral feebly rugose.

Euoniticellus pallens (Olivier, 1789)

(Plate No. 6: Fig. 14 a, b)

Scarabaeus pallens Olivier, 1789, 3: 170, pl. 38, fig. 203.

Oniticellus concinnus, Gené, 1836, 39: 25-33.

Oniticellus speculifer, Ménétriés, 1849, VI: 59.

Oniticellus pallens, D'Orbigny, 1898, XXIX: 227 - Arrow, 1931, III: 375, 377 - Balthasar,
1935b, 115: 102 - Paulian, 1941, 38: 64, 65.

Oniticellus (Euoniticellus) pallens, Balthasar, 1963b, II: 75.

Euoniticellus pallens, Janssens, 1953, 11: 56, fig. 57, 58, 59 - Bezdek and Krell, 2006a, 3:
156 – Krajcik, 2006: 61.

Diagnostic characters

Colour: testaceous; pronotum and head with slightly metallic green suffusion; closely hairy; elytra with long yellow hairs at posterior; antennal club light black; tarsi slightly metallic. Shape: parallel sided and elongate. Head: clypeus straight in front; genae not much bluntly produced. Pronotum: strongly and closely punctate; posterior region at base with a short a median groove; front angles blunt and rectangular; lateral sides rounded; base angulate; four shining spots in middle. Elytra: lightly striate; intervals flat, finely and feebly punctate; a short triangular scutellum. Pygidium: opaque, impressed at apex; finely and sparsely punctate with a median smooth spot in middle. Legs: protibiae quadridentate. Venter: metasternum finely and closely punctate with a very fine median line; metepisternum feebly rugose externally and sparsely punctate behind mesocoxae.

External male genitalia (Plate No. 6: Fig. 14 b)

Phallobase almost thrice in length as parameres; parameres obliquely placed ventrally and apex obliquely truncate with tips sharply pointed.

Genus *Oniticellus* Dejean, 1821

Oniticellus Dejean, 1821: 53 - Serville, 1825, X: 356 - Lacordaire, 1856, III: 110 - Peringuey, 1901, XII: 160 - Boucomont and Gillet, 1921, IV: 21 - Arrow, 1931, III: 79, 375 - Balthasar, 1935b, 115: I: 25, 99 - Paulian, 1945, III: 129; Janssens, 1953, 11: 105 - Balthasar, 1963b, II: 70 - Bezdek and Krell, 2006a, 3: 157.

Pseudoniticellus, Kraatz, 1895, XXXIV, (1): 142 - Paulian, 1945, III: 136.

Type species: *Scarabaeus cinctus* Fabricius, 1775.

Diagnostic characters

Black and shining; parallel sided and elongate; entirely devoid of hairs but with a fringe of yellow hairs on posterior region of elytra; clypeus rounded in front and feebly excised in middle, slightly impressed at sides, entirely impunctate without any carina; ocular lobes angular; pronotum impunctate with a strong median groove in middle; elytra strongly striate, intervals convex and smooth; pygidium finely rugose; metasternum very finely punctate with a strong smooth median line.

Oniticellus cinctus (Fabricius, 1775)

(Plate No. 6: Fig. 15 a, b)

Scarabaeus cinctus Fabricius, 1775: 30.

Scarabaeus serratipes, Drury, 1770, I: 79, pl. 36, fig. 8, 9.

Onitis diadema, Wiedemann, 1819, I, 3: 159.

Oniticellus cinctus var. *diadema*, Boucomont, 1914, LXXXIII: 255.

Oniticellus cinctus, Westwood, 1842: 2, pl. 1 fig. 3 - Boucomont, 1914, LXXXIII: 255 - Arrow, 1931, III: 375, 379 - Balthasar, 1935b, 115: 103 - Paulian, 1945, III: 130, fig. 70 - Janssens, 1953, 11: 110 - Balthasar, 1963b, II: 77, pl. 10, fig. 5 - Bezdek and Krell, 2006a, 3: 157 - Krajcik, 2006: 78.

Diagnostic characters

Colour: piceous and shining; a border along sides of elytra from shoulder to posterior region meeting at sutural line and apex of pygidium yellow; entirely devoid of hairs but with a fringe of yellow hairs on posterior region of elytra and few hairs on legs; antennal club piceous; tarsi dark brown. Shape: parallel sided and elongate. Head: clypeus rounded in front, feebly excised in middle, slightly impressed at sides, entirely impunctate without any carina; genae angular. Pronotum: impunctate with a strong median groove; front angles blunt; lateral sides rounded; base flat. Elytra: strongly striate; intervals convex and smooth. Pygidium: finely rugose. Venter: metasternum very finely punctate with a strong smooth median line, lateral sides rugosely punctate. Legs: protibiae quadridentate.

External male genitalia (Plate No. 6: Fig. 15 b)

Phallobase almost thrice in length as parameres; parameres bluntly rounded at apex, with a sinuation near base on dorsal side, and two processes on ventral side.

Genus *Liatongus* Reitter, 1893

Type species: *Liatongus phanaeoides* (Westwood, 1839).

Diagnostic characters:

Body is elongate, brownish in colour, very minute scutellum, head and clypeus prominent, male and female differ significantly, in male a very long horn is present.

Identification key to the species of Genus *Liatongus*

1. Black in colour but legs are reddish, clypeus is finely punctured, without setae, head and pronotum is shining but elytra is comparatively less shiny, pygidium is misty...........***Liatongus gagatinus* (Hope, 1831)**

- Brown in colour……….……………………………………………….**2**

2. Elytra is somewhat more brownish, legs are the same of elytral colour, elytra is weekly striate, pygidium is not strongly punctured……………..………..***Liatongus mergacerus* (Hope, 1831)**

- Brownish, dorsal surface of the body is more smeared then ventral surface, elytra is strongly striate……………………………………………………………………
…………………………***Liatongus phanaeoides* (Westwood, 1839)**

Liatongus gagatinus (Hope, 1831)

(Plate No. 6: Fig. 16 a, b)

Liatongus gagatinus (Hope, 1831), 22, Arrow, 1931, III: 311, pl. 12, fig. 11, 12

Onthophagus brama Redtenbacher, 1848, 2, IV, 521

Diagnostic characters:

Black but legs are reddish, clypeus is finely punctured, without setae, head and pronotum is shining but elytra is comparatively less shiny, sides of pronotum is weekly puntured, pygidium is misty, metasternum is smooth in the middle but very opaque at the ends. Male has a distinct horn.

External male genitalia (Plate No. 6: Fig. 16 b)

Phallobase twice in length as parameres. Parameres a little broader at base and slightly tapered distally, excised a basal half on dorsal side with tips little pointed.

Liatongus mergacerus (Hope, 1831)

(Plate No. 65: Fig. 17 a, b)

Onthophagus mergacerus (Hope, 1831) 22- Arrow, 1931, III: 369

Oniticellus mergacerus Harold 1874 XII: 94

Diagnostic characters:

Brown in colour, head and pronotum is more blackish and shiny, elytra is somewhat more brownish, legs are the same of elytral colour, clypeus is deeply punctured, elytra is striate, pygidium is not strongly punctured, protibia is quadridentulate. In male cephalic and thoracic horns are present.

External male genitalia (Plate No. 6: Fig. 17 b)

Phallobase longer than parameres. Parameres broad at base slightly curving anteriorly and blunt at tips.

***Liatongus phanaeoides* (Westwood, 1839)**

(Plate No. 7: Fig. 18 a, b)

Liatongus phanaeoides (Westwood, 1839) 55, pl 9, fig, 3- Arrow, 1931, III: 364

Onthophagus excavatus Redtenbacher, 1848, (2) IV: 523

Diagnostic characters:

Brownish, dorsal surface of the body is more smeared then ventral surface, head and pronotum densely punctuate, elytra is strongly striate, continuous interludes with minute granules, while abdomen and pygidium are not punctured. Metasternum is shining but metasternal shield is smeared at the corners. Male has strongly developed horn.

External male genitalia (Plate No. 7: Fig. 28 b)

Phallobase more than twice in length as parameres. Parameres broad at base and tapered distally with apex rounded.

Genus *Tiniocellus* Peringuey, 1900

Tiniocellus Peringuey, 1901, XII: 116 - Arrow, 1908, (8), 1: 183 - Boucomont, 1923, XI:

53 - Janssens, 1953, 11: 56 - Balthasar, 1963b, II: 107- Bezdek and Krell, 2006a, 3:157.

Type species: *Oniticellus spinipes* Roth, 1851.

Diagnostic characters

Dark brown; densely setose upon dorsal and ventral surface; head not carinate, clypeus rounded and feeble excised, lateral sides sinuate; pronotum entirely rugosely punctate with a deep median groove at base; elytra punctate, striate, intervals flat with minute granules; pygidium thinly setose, a little hollowed on each side at base, metasternum flat and closely punctate with an impression at base, lateral side sparsely granulate.

Tiniocellus spinipes (Roth, 1851)

(Plate No. 7: Fig. 19 a, b)

Oniticellus spinipes Roth, 1851, 17 (1): 128 - Arrow, 1931, III: 378 - Balthasar, 1935b,
115: 102 - Janssens, 1939b: 12, 16 - Krajcik, 2006: 79.
Oniticellus variegatus, Fahraeus, 1857, II: 320.
Oniticellus humilis, Gerstaecker, 1871, 37: 52.
Oniticellus imbellis, Bates, 1891, XXIV: 13.
Oniticellus setifer, Kraatz, 1895: 143.
Oniticellus modestus, Arrow, 1908, (8), 1: 182.
Tiniocellus spinipes, Peringuey, 1901, XII: 116 - D'Orbigny, 1916: 29 - Janssens, 1953,
11: 58, 60 - Balthasar, 1963b, II: 108 - Bezdek and Krell, 2006a, 3: 157.

Diagnostic characters

Colour: opaque and dark brown; closely clothed with short dense hairs both dorsally and ventrally; metasternum metallic and shining; antennal club piceous and tarsi brown; a fringe of long yellow hairs present on posterior part of elytra. Shape: parallel sided and elongate. Head: clypeus rounded in front, deeply excised in middle and finely punctate without any carina; ocular lobes rounded; frons more closely punctate. Pronotum: entirely rugosely punctate with a deep median groove in middle of base; front angles blunt; lateral sides and base rounded. Elytra: punctate striate; intervals flat with minute granules. Pygidium: thinly setose, a little hollowed on each side at base. Venter: metasternum flat and closely punctate with an impression at base and lateral sides sparsely granulate. Legs: protibiae quadridentate.

External male genitalia (Plate No. 7: Fig. 19 b)

Phallobase more than thrice in length as parameres; parameres slightly broader distally with apex almost rounded with two processes on ventral side.

Tribe ONITINI Laporte, 1840

Onitides Laporte, 1840, 2: 88.

Type genus: *Onitis* Fabricius, 1798: 25.

Diagnostic characters

Elongate, flat and strongly convex; dorsally glabrous without any hair, sometimes pygidium closely hairy; about 15 to 25 mm in length; antennae 9 segmented with club relatively small; mouthparts especially maxillae with their membranous lobe broad, well pronounced and often fully visible in dorsal view; pronotum simply punctate or entirely smooth with a pair of well-marked small impressions in middle of base; scutellum visible; elytra with 10 striae and a strongly raised longitudinal carina contiguous to 8th stria; protibiae in male strongly elongate and curved inwards with inner distal end often very strongly protruding as a sharply pointed finger like projection; terminal spur absent; in females, protibiae stout with distinct terminal spur;

protarsi absent; meso and meta tibiae short and very strongly dilated towards apices.

Genus *Onitis* Fabricius, 1798

Onitis Fabricius, 1798: 2 - Fabricius, 1801, I: 26; Arrow, 1931, III: 386 - Janssens, 1937,
11: 15 - Balthasar, 1963b, II: 26 - Bezdek and Krell, 2006b, 3: 158.
Type species: *Scarabaeus inuus* Fabricius, 1781 (=*Scarabaeus sphinx* Fabricius, 1775).

Diagnostic characters

Oblong with legs stout; protarsi absent; meso and meta tibiae strongly dilated; antennae 9 segmented; head with a clypeofrontal suture either complete or interrupted by a tubercle; clypeus entire or feeble excised in middle at front margin; pronotum with two basal impressions on each side of middle at base, sparsely or closely or strongly punctate or entirely smooth; scutellum visible; elytra with a strong lateral carina, finely striate; pygidium smooth or densely hairy. parameres equal in length to phallobase.

Identification key to the species of Genus *Onitis*

1. Metasternum transversely excavated; pronotum weekly punctured; femur notched or lobed………..……….***Onitis excavatus* Arrow, 1931**
- Metasternum narrow; pronotum feebly punctate; mesofemur without any process or lobe…………………..……..***Onitis falcatus* (Wulfen, 1786)**
2. Metasternum longitudinally grooved in front; protibiae quadridentate; mesofemur not lobed in middle…….***Onitis philemon* Fabricius, 1801**
- Metasternum not longitudinally grooved in front; protibiae tri or quadridentate; mesofemur lobed in middle……………………….…………………………..……..**3**

3. Protibiae tridentate with a terminal blunt process; a minute tooth present near base beneath; mesofemur strongly lobed in middle with two teeth near extremity a little far apart……………………………..……***Onitis subopacus* Arrow, 1931**

\- Protibiae quadridentate; 4th teeth blunt, joined with 3rd; ventral surface of protibiae at end serrated; mesofemur with a strong lobe in middle of posterior and a tooth at extremity.……..***Onitis virens* Lansberge, 1875**

Onitis excavatus Arrow, 1931

(Plate No. 7: Fig. 20)

Onitis excavatus Arrow, 1931, III: 391, pl. 12, fig. 19

Diagnostic characters

Colour: Dark black and shining, shape: slightly convex; pronotum: smooth, without longitudinal groove and weekly rugulose; elytra: clearly striate, pygidium: slightly subopacue.

Onitis falcatus (Wulfen, 1786)

(Plate No. 7: Fig. 21 a, b)

Scarabaeus falcatus Wulfen, 1786: 14, pl. 2, fig. 17 (♂).

Onitis falcatus, Lansberge, 1875, XVIII: 126 (♂♀) - Boucomont and Gillet, 1921, IV: 17, 19 - Arrow, 1931, III: 392, pl. 11, fig. 9, 10 - Balthasar, 1935b, 115: 93 - Janssens, 1937, 11: 44, fig. 37 - Paulian, 1945, III: 142 - Balthasar, 1963b, II: 33, pl. 4, fig. 1 - Bezdek and Krell, 2006b, 3: 159.

Onitis hymalajicus, Redtenbacher, 1848, 4 (2): 518.

Onitis sphinx, Herbst, 1789, 2: 186, pl. 13, fig. 8 - Fabricius, 1801: 29.

Diagnostic characters

Colour: piceous; pronotum and head a little shining; elytra and pygidium opaque; dorsally devoid of hairs; ventral surface, lateral and anterior part of metasternum and legs, clothed with yellow hairs; mouthparts dark red; antennal club yellow. Shape: oval and convex. Head: clypeus rugose feeble excised in middle, separated from frons by a widely interrupted clypeofrontal caina, a slight transverse carina present behind it and a short median tubercle present in between; frons granular; an oblique carina separates clypeus from smooth genae. Pronotum: feebly and sparsely punctate; front angles a little pointed; lateral sides and base rounded. Elytra: feebly striate; 2^{nd} and 4th intervals wider than others. Pygidium: opaque and impunctate. Legs: protibiae quadridentate; 3 minute teeth present at end on lower edge (Fig. 208c), terminal spur sharp; mesofemora without any tooth and impunctate; mesotibiae triangular; trochanter of metafemora not toothed; metatibiae triangular (Fig. 208b). Venter: prosternum narrow; propleuron densely hairy; mesosternum closely hairy; metasternum flat, feeble punctate in middle and closely hairy, roughly punctate at front, lateral side more closely hairy and punctate.

External male genitalia (Plate No. 7: Fig. 21 b)

Phallobase and parameres almost equal in length; parameres joined together with membrane in 3/4 part, with a little sinuation on dorsal side in middle, tapering distally, with apex narrow but not sharply pointed.

Onitis philemon Fabricius, 1801

(Plate No. 8: Fig. 22 a, b)

Onitis philemon Fabricius, 1801, I: 30 - Arrow, 1931, III: 393, pl. 11, fig. 3, 4 - Balthasar, 1935b, 115: 95 - Janssens, 1937, 11: 53, fig. 41 - Paulian, 1945, III: 144 - Balthasar, 1963b, II: 41, pl. 5, fig. 2 - Bezdek and Krell, 2006b, 3: 159.

Onitis distinctus, Lansberge, 1875, XVIII: 138.

Onitis minor, Lansberge, 1875, XVIII: 139.

Diagnostic characters

Colour: metallic green or brown; dorsally devoid of hairs; ventral surface, anterior and lateral part of metasternum, legs and mouthparts with long yellow hairs; antennal club light yellow. Head: clypeus rugose, parabolic, excised in middle, separated from frons by a narrowly interrupted clypeofrontal carina, a tubercle present behind it and a slightly elevated carina in front of it; frons minutely granular; an oblique carina separates clypeus from smooth genae. Pronotum: strongly, closely and uniformly punctate without a well marked median line; front angles a little pointed; lateral side rounded; base angulate. Elytra: striate; intervals very feebly punctate; 1st, 3rd, and 5th intervals convex. Pygidium: feebly and sparsely punctate. Venter: prosternum narrow; propleuron densely hairy and confluently punctate; mesosternum smooth, closely hairy; metasternum finely punctate in middle with a strong median groove in front; lateral sides closely hairy and more closely punctate.

External male genitalia (Plate No. 8: Fig. 22 b)

Phallobase a little shorter than parameres; parameres joined together with membrane in 3/4 basal part, tapered distally with acutely pointed and slightly curved inward.

***Onitis subopacus* Arrow, 1931**

(Plate No. 8: Fig. 23 a, b)

Onitis subopacus Arrow, 1931, III: 395.
Onitis philemon, Lansberge, (nec Fabricius), 1875, XVIII: 133.
Onitis philemon, Boucomont, 1914, LXXXIII: 336 - Boucomont and Gillet, 1921, IV: 19.
Onitis subopacus, Janssens, 1937, 11: 51, fig. 38 - Balthasar, 1963b, II: 38, pl. 5, fig. 1 - Bezdek and Krell, 2006b, 3: 159.

Diagnostic characters

Colour: piceous; elytra opaque, pronotum and head slightly metallic; dorsally devoid of hairs; ventral surface, anterior and lateral part of metasternum, legs and mouthparts with long yellow hairs. Shape: elongate and convex. Head: clypeus semicircular, rugose, separated from frons by a widely interrupted clypeofrontal carina with a tubercle behind it and a slightly elevated carina in front of it; frons and genae minutely granular; an oblique carina separates clypeus from genae. Pronotum: closely and uniformly punctate; front angles a little pointed; lateral side rounded; base angulate. Elytra: striate; intervals impunctate; 1st, 3rd and 5th intervals convex. Pygidium: opaque and impunctate. Venter: prosternum narrow; propleuron densely hairy; mesosternum granular and closely hairy; metasternum finely and closely punctate, lateral side and metepisternum closely hairy and more closely punctate.

External male genitalia (Plate No. 8: Fig. 23 b)

Phallobase almost as long as parameres; parameres joined together with membrane, broad at base and tapered distally with apex a little curved inward and tips pointed.

***Onitis virens* Lansberge, 1875**

(Plate No. 8: Fig. 24 a, b)

Onitis virens Lansberge, 1875, XVIII: 135 - Boucomont and Gillet, 1921, IV: 19 - Arrow, 1931, III: 396, pl. 12, fig. 20, 21 - Janssens, 1937, 11: 51, fig. 39, 40 - Paulian, 1945, III: 144 - Balthasar, 1963b, II: 40 - Bezdek and Krell, 2006b, 3: 159.
Onitis amplectens, Lansberge, 1875, XVIII: 136.

Diagnostic characters

Colour: deep metallic green; dorsally devoid of hairs; ventral surface, metasternum and parts of legs clothed with yellow hairs. Shape: oval and convex. Head: clypeus entirely rugose, separated from frons by an interrupted clypeofrontal carina, with a strong transverse carina in front and a strong median tubercle behind it; frons smooth with some granules; an oblique carina separates clypeus from smooth genae. Pronotum: strongly and closely punctate; front angles a little pointed; lateral sides and base rounded. Elytra: deeply striate; intervals very feebly punctate. Pygidium: smooth and sparsely punctate. Venter: prosternum narrow; propleuron smooth in middle, sides hairy; mesosternum granular, closely hairy; metepisternum and mesepimeron densely hairy; metasternum smooth, feeble punctate in middle, closely hairy at front; lateral side more closely hairy and punctate. Legs: protibiae long, slender, curved, and quadridentate; 4th teeth blunt, joined with 3rd; lower edge of protibia at end serrated, terminal spur pointed and curved; mesofemora with a strong lobe in middle of posterior and a tooth at extremity; trochanter of metatibiae toothed.

External male genitalia (Plate No. 8: Fig. 24 b)

Phallobase almost as long as parameres; parameres having a notch and joined together with membrane, narrow at base and tapered distally with apex a little curved inward and tips pointed.

Tribe Onthophagini Burmeister, 1846

Onthophagidae Burmeister, 1846: [1].
Alloscelini, Janssens, 1946, 2 (18): 10.
Type genus: *Onthophagus* Latreille, 1802: 141.

Diagnostic characters

Strongly convex and oval; large to small sized; tunneller; male usually with one or two horns on head; second segment of labial palpi longer than first, third very small sometimes scarcely visible or absent; antennae 9 segmented; meso and meta tibiae broad, short, triangular, apex of which strongly dilated; meso and meta femora not elongate somewhat broad in middle; protarsi present in both sexes; protibiae not elongate rather broad; terminal spurs of protibiae movable; mesocoxae parallel; scutellum not visible; pronotum without any basal impressions; elytra with one lateral carina; sexual dimorphism prominent.

Identification key to the genera of tribe Onthophagini

1. Meso and meta tarsi neither broad nor flattened; genae not strongly produced; clypeus not produced into a lobe like structure, pronotum is closely punctuated and anterior angles of pronotum not hollowed on ventral surface…………..……………….……***Caccobius* Thomson, 1859**

- Meso and meta tarsi neither are flattened; pronotum is not closely punctuated………………………………………***Caccophilus* Jekel, 1872**
- Anterior angles of pronotum not hollowed on ventral surface………. ……………………………………………………………………….…**2**

2. Protibiae elongate, slender and curved with a long terminal finger like spur and quadridentate, external teeth small, widely separated, at right angles to inner margin; pale yellow in colour; vertex in males, always with two horns;……………….……………….***Digitonthophagus* Balthasar, 1959**

- Protibiae may be elongate or broad but always without finger like spur, may be tri or quadridentate, external teeth broad not widely separated sometimes at right angles to inner margin; colour variable; head in male with two horns or one horn or entirely without any horn ……………………………………………***Onthophagus* Latreille, 1802**
- Protibiae elongate and toothed; head in male with two horns…………… ………………………..……….……***Parascatonomus* Paulian, 1932**

Genus *Caccobius* Thomson, 1859

Caccobius Thomson, 1859, 2: 80 - Harold, 1867b, 2: 5 - Arrow, 1931, III: 141 - Balthasar,
1963b, II: 113 - Löbl, Krell, Ziani, and Král, 2006, 3: 160.
Type species: *Scarabaeus schreberi*, Linnaeus, 1767.

Diagnostic characters

Very small sized, convex and broadly oval; antennae 8 segmented; front angles of pronotum deeply hollowed on ventral surface; pronotum strongly or closely or with annular punctures and one lateral carina, closely hairy or smooth; scutellum not visible; elytra striate with one lateral carina; protibiae quadridentate, very short and broad with terminal tooth placed obliquely but straight, its anterior edge forming a right angle with inner edge of tibiae; in some species terminal tooth of protibiae rectangular not pointed, thin and transparent, often bent at right angle to inner margin; meso and meta tibiae dilated at end.

Caccobius (Caccobius) denticollis **Harold, 1867**

(Plate No. 9: Fig. 25 a, b)

Caccobius (Caccobius) denticollis Harold, 1867, II:5 - Arrow, 1931, III: 155, fig. 13

Diagnostic characters

Colour: Black and shining, male and female follows a different colour pattern, in male, elytra is black with yellow hind margin while female has the somewhat brownish with yellow hind margin; legs and antennal club are reddish black; Shape: very small sized, convex and broadly oval. Head: smooth, devoid of hair; clypeus acuminate, lateral sides straight; clypeofrontal carina feeble, an oblique carina separates clypeus from genae. Pronotum: coarsely, strongly and closely punctate; front angles acute and pointed; lateral sides and base strongly rounded. Elytra: finely striate; intervals flat, sparsely but strongly punctate. Pygidium: coarsely but closely punctate. Venter: metasternum sparsely punctate in middle but more closely punctate at sides.

External male genitalia (Plate No. 9: Fig. 25 b)

Phallobase as long as parameres; parameres curved with apex blunt and curved sharply**.**

Subgenus *Caccophilus* Jekel, 1872

Caccobius subgenus *Caccophilus* Jekel, 1872, (2): 405 - Balthasar, 1963b, II: 113, 117 -
Löbl, Krell, Ziani, and Král, 2006, 3: 160.
Type species: *Caccobius himalayanus* Jekel, 1872.

Diagnostic characters

Dorsal surface setose; clypeus pointed or rounded or bilobed at front; in males, head one or two horned or without any horn; pronotum strongly and closely punctate or with some annular punctures; elytra shining or opaque, maculate with an orange bar at posterior region; prosternum with a single carina directed from procoxae towards sides of pronotum

Identification key to the species of Subgenus *Caccophilus*

1. Clypeus acuminate; dorsal surface with long hairs; in males, head with two horns…………………………………………………………………………… …………………………***Caccobius (Caccophilus) diminutivus* Walker, 1858**
2. Clypeus bilobed; in males, head with one horn……………………..……………………………………………………… ………………………***Caccobius (Caccophilus) unicornis* (Fabricius, 1798)**

Caccobius (Caccophilus) diminutivus **Walker, 1858**

(Plate No. 9: Fig. 26)

Copris diminutivus Walker, 1858, (3) II: 208.

Onthophagus setulosus, Motschulsky, 1863, 36 (1): 459.

Caccobius diminutivus, Arrow, 1931, III: 142, 143 - Krajcik, 2006: 18.

Caccobius (Caccophilus) diminutivus, Balthasar, 1949, 26: 8, 43 - Balthasar, 1963b, II:
141 - Löbl, Krell, Ziani, and Král, 2006, 3: 160.

Diagnostic characters

Colour: piceous and shining; legs and antennal club red; dorsally universally clothed with erect, rather sparse, long and pale setae. Shape: very small sized, convex and broadly oval. Head: very sparsely hairy; clypeus acuminate, lateral sides straight; clypeofrontal carina feeble, an oblique carina separates clypeus from genae. Pronotum: coarsely, strongly and closely punctate; front angles acute and pointed; lateral sides and base strongly rounded. Elytra: finely striate with 7 striae; intervals flat, sparsely but strongly punctate. Pygidium: coarsely but closely punctate. Venterl: metasternum sparsely punctate in middle but more closely punctate at sides.

Caccobius (Caccophilus) unicornis **(Fabricius, 1798)**

(Plate No. 9: Fig. 27 a, b)

Copris unicornis Fabricius, 1798: 33.

Onthophagus nitidiceps, Fairmaire, 1893, 37: 304.

Onthophagus unicornis, Boucomont, 1914, XLVI: 236.

Caccobius yamauchii, Matsumura, 1936, XI: 66.

Caccobius unicornis, Arrow, 1931, III: 142, 145 - Paulian, 1945, III: 83 - Krajcik, 2006: 20.

Caccobius (Caccophilus) unicornis, Balthasar, 1949, 26: 10, 44 - Balthasar, 1963b, II: 142 - Löbl, Krell, Ziani, and Král, 2006, 3: 161.

Diagnostic characters

Colour: head, pronotum and ventral surface piceous and shining; legs, elytra, antennal club, and mouthparts dark yellow; dorsally and ventrally clothed with minute pale setae. Shape: very small, broadly oval and convex. Head: clypeus bilobed in middle; eyes small seen from above; genae rounded. Pronotum: strongly punctate; front angles blunt; lateral margins and base rounded. Elytra: finely striate; 7th striae strongly curved; intervals flat minutely and sparsely punctate. Pygidium: finely not closely punctate. Legs: protibiae quadridentate. Venter: metasternum finely punctate; lateral side closely coarsely pitted.

External male genitalia (Plate No. 9: Fig. 27 b)

Phallobase thrice in length as parameres; parameres triangular, pointed at apex.

Genus *Cleptocaccobius* Cambefort, 1984

Type species: *Caccophilus signaticollis* D'Orbigny, 1902

Diagnostic characters:

Very small sized, convex and broadly oval; antennae 8 segmented; front angles of pronotum deeply hollowed on ventral surface; pronotum is not closely punctured with or without carina hairy and smooth; scutellum not visible; elytra striate; protibiae quadridentate, terminal tooth of protibiae is short in male, while long and very strident in female.

Cleptocaccobius inermis (Arrow, 1931)

(Plate No. 9: Fig. 28)

Cleptocaccobius inermis (Arrow, 1931), III: 147

Diagnostic characters

Colour: head, pronotum and ventral surface black and shining; legs, elytra, antennal club, and mouthparts are reddish brown; Shape: very small, broadly oval and convex. Head: clypeus bilobed in middle; eyes small seen from above; genae rounded. Pronotum: strongly but not closely punctate; front angles blunt; lateral margins and base rounded. Elytra: finely striate; intervals flat and sparsely punctate. Pygidium: punctate. Legs: protibiae quadridentate. Venter: metasternum finely punctate; lateral side closely coarsely pitted.

Genus *Digitonthophagus* Balthasar, 1959

Onthophagus subgenus *Digitonthophagus* Balthasar, 1959, 33: 464 - Balthasar, 1963b, II: 165.

Digitonthophagus, Zunino, 1981, 3: 408 - Kabakov and Napalov, 1999, 37: 91 - Kabakov, 2006: 331 - Löbl, Krell, Ziani, and Král, 2006, 3: 165.

Type species: *Scarabaeus bonasus* Fabricius, 1775.

Diagnostic characters

Medium to large sized; yellowish brown; pronotum green sometimes red with some granules; head and pronotum with metallic lustre; lateral sides of pronotum yellow; elytra yellow; dorsal surface a little shining with a few short hairs; protibiae elongate, slender, curved with a long terminal finger like spur and quadridentate, external teeth small, widely separated at right angles to inner margin in males (Fig. 158d); clypeus rounded at front; vertex with a pair of backwardly directly horns in males at posterior region of head, sometimes a tubercle present in between horns; in females, head with two strong and straight carina or sometimes with two horns like males; front margin of pronotum strongly produced; basal segment of antennae saw like or denticulate as in subgenus Serrophorus; apical end of meta tibiae lobed.

Digitonthophagus bonasus **(Fabricius, 1775)**

(Plate No. 10: Fig. 29 a, b)

Scarabaeus bonasus Fabricius, 1775: 23 - d'Orbigny, 1898, XXIX: 218.
Onthophagus bonasus, Boucomont and Gillet, 1921, IV: 41 - Arrow, 1931, III: 229, 231, pl. 13, fig. 5, 6 - Krajcik, 2006: 94.
Onthophagus (Onthophagus) bonasus, Paulian, 1945, III: 88, 101.
Onthophagus (Digitonthophagus) bonasus, Balthasar, 1963b, II: 296, pl. 12, fig. 5.
Digitonthophagus bonasus, Kabakob and Napalov, 1999, 37: 91 - Kabakov, 2006: 332 - Löbl, Krell, Ziani, and Král, 2006, 3: 161

Diagnostic characters

Colour: elytra, pronotal and metasternal border, ventral surface of all femora, abdomen and antennal club yellow; middle of pronotum, head and a spot on each femur metallic green; legs on dorsal view dark brown black; venter and pygidium closely hairy; dorsally with sparse and small hairs. Head: clypeus finely and closely granulate, reflexed in front, separated from frons by a strongly curved clypeofrontal carina; frons and genae sparsely granulate; frons with a pointed tubercle in middle; vertex with a pair of backwardly directed horns whose surface minutely granulate. Pronotum: sparsely granulate in middle with a strong median groove; on each side of groove present one tubercle in middle; front angles acutely produced, lateral sides feebly sinuate; base angulate. Elytra: finely striate; 7th striae strongly curved; interval minutely punctate. Pygidium: sparsely punctate. Legs: protibiae quadridentate. Venter: metasternum smooth in middle, lateral side rather closely punctate**.**

External male genitalia (Plate No. 10: Fig. 29 b)

Phallobase almost double as long as parameres; parameres a little narrow at base and broader distally, with acute triangular processes ventrally.

Genus *Onthophagus* Latreille, 1802

Onthophagus Latreille, 1802, III: 141 - Arrow, 1931, III: 159 - Balthasar, 1963b, II: 153 -
Löbl, Krell, Ziani, and Král, 2006, 3: 162 - Krajcik, 2006: 86.
Type species: *Scarabaeus taurus* Schreber, 1759.

Diagnostic characters

Medium to small sized; oval, flat, and convex; entirely smooth or clothed closely or sparsely with setae on dorsal or ventral surface; clypeus variable in shape, rounded or bilobed or acuminate in front margin; pronotum closely or sparsely punctate or rugose or granulate with some smooth area, front angles acute or blunt, base rounded; scutellum not visible; elytra covering abdomen, bearing a single lateral carina and 7 dorsal striae, 7th striae usually strongly curved but sometimes parallel with 6th one; pygidium bearing a transverse ridge parallel with base and continuous with lateral carina of abdomen, coinciding with margins of elytra, but sometimes absent;

mesometasternal suture nearly straight; metasternal shield broad with anterior part flat, sloping or sometimes vertical in middle and occasionally forming a short compressed process; abdomen short, 6th sternite extremely short in males; protibiae tri or quadridentate; meso and meta tibiae dilating greatly from base to extremity with terminal margin nearly straight, but sometimes trilobod; antennae 9 segmented but sometimes 8 segmented, basal segment serrated in some; sexual dimorphism strongly developed; some dung feeders and some carrion feeders.

Identification key to the subgenera of *Onthophagus*

1. Elytral base with minute elevations in middle; pronotum closely or sparsely punctate; pygidium always margined at base; in males, teeth of protibiae broadened and obliquely truncate; fairly long ……....………………..……………..***Colobonthophagus* Balthasar, 1963**
- Pronotum feebly punctate; in males, teeth of protibiae are short; …….……………………..…….……………..**Matashia Matsumara, 1938**
- Pronotum strongly very closely evenly punctate …………………..……….………………***Indonthophagus Kabakov,* 2006**
- Pronotum strongly not very closely punctate dorsally and strongly and closely punctate at lateral sides…………………….………….***Phanaeomorphus* Balthasar, 1935**
- Pronotum strongly not very closely but evenly punctate ……………………………………………………………………….**2**

2. Front angles blunt………..…..……….…..***Palaeonthophagus* Zunino, 1979**
- Front angles rather sharp…….……..……..… ***Serrophorus* Balthasar 1935**
- Not fitting in above subgenera………..***Onthophagus speciesincertaesedis***

Subgenus *Colobonthophagus* Balthasar, 1963

Onthophagus subgenus *Colobonthophagus* Balthasar, 1963b, II: 164 - Löbl, Krell, Ziani,and Král, 2006, 3: 163.
Type species: *Scarabaeus tragus* Fabricius, 1792.

Diagnostic characters

Shining black or green, sometimes with metallic lustre on dorsal surface; dorsally devoid of hairs or with very minute sparse hairs; pronotum sparsely or closely punctate without granules; in males, vertex either with a pair of horns or a single horn or toothed elevations at posterior region of head adjoining each eye while females with a strong clypeofrontal carina and another carina on vertex on posterior part head; clypeus rounded or feeble emarginate at front; protibiae quadridentate, terminal teeth of protibiae at right angle to inner margin; terminal spurs short and spatulate in males; elytral base with or without two minute elevations; pygidium punctate.

Identification key to the subgenera of Subgenus *Colobonthophagus*

1. Dark metallic green; elytral suture without a minute elevation behind base; in males, vertex with a pair horn at posterior region of head reaching at tips arising near each eye……………………………………………………………………… ……………***Onthophagus (Colobonthophagus) dama*** **(Fabricius, 1798)**
2. Front angles of pronotum blunt but not produced; pronotum closely but not strongly punctate not, punctures fine; 7th elytral stria strongly curved with 6th; vertex either with two horns or with a single horn or with three teeth……………***Onthophagus (Colobonthophagus) hindu*** **Arrow, 1931**

- Front angles of pronotum bluntly produced; pronotum closely and strongly punctate with punctures at lateral side coarse; 7th elytral stria almost parallel with 6th; in both males and females, vertex with a pair of backwardly directed horns, united by a strong carina and have short tubercle in middle …………………………………………………………………………..**3**

3. In males, vertex with a pair of long horns, compressed laterally, diverged strongly at base, curved outwardly with tips pointed; a strong tooth present in middle of anterior edge; pronotum uniformly closely punctate ……… ***Onthophagus (Colobonthophagus) ramosus*** **(Wiedemann, 1823)**

- In males, vertex with a pair of long straight horns reaching before base of pronotum; sides of pronotum behind horns depressed and smooth, strongly punctate at middle... ....***Onthophagus (Colobonthophagus) ramosellus*** **Bates, 1891**

Onthophagus (Colobonthophagus) dama **(Fabricius, 1798)**

(Plate No. 10: Fig. 30 a, b)

Copris dama Fabricius, 1798: 32.

Scarabaeus aeneus, Olivier, 1789, I, 3: 131.

Onthophagus zubaci, Balthasar, 1932, 93: 151.

Onthophagus dama, Arrow, 1931, III: 279, 280 - Krajcik, 2006: 99.

Onthophagus (Onthophagus) dama, Balthasar, 1963b, II: 325, pl. 12, fig. 6.

Onthophagus (Colobothophagus) dama, Löbl, Krell, Ziani and Král, 2006, 3: 163.

Diagnostic characters

Colour: dark green or black green; shining entirely; hairs absent on both dorsal and ventral surface; mouthparts and tarsi red; antennal club yellow. Shape: oval and convex. Head: clypeal margin rounded, a little reflexed. Pronotum: finely and sparsely punctate; front angles blunt; lateral angles and base rounded. Elytra: finely striate; intervals flat, sparsely and finely punctate in middle while lateral sides closely punctate. Pygidium:

moderately punctate. Legs: protibiae quadridentate. Venter: metasternum finely punctate

External male genitalia (Plate No. 10: Fig. 30 b)

Phallobase more than twice in length as parameres; parameres broad at base, and slightly tapered distally, apex curved ventrally, with tips pointed.

***Onthophagus (Colobonthophagus) hindu* Arrow, 1931**

(Plate No. 10: Fig. 31 a, b)

Onthophagus hindu Arrow, 1931, III: 279, 289 - Krajcik, 2006: 109.
Onthophagus (Colobonthophagus) hindu, Balthasar, 1963b, II: 381, fig. 204 - Löbl, Krell,
Ziani and Král, 2006, 3: 163.

Diagnostic characters

Colour: piceous and shining; antennal club dark red reaching to black; tarsi red; dorsally devoid of hairs; ventral surface lightly red, sparsely hairy on legs. Shape: oval not convex. Head: clypeus a little reflexed, bilobed in front; clypeofrontal carina feeble and transverse; genae rounded. Pronotum: finely and closely punctate; front angles blunt; lateral sides and base rounded. Elytra: finely striate; elytral intervals flat, minutely and sparsely punctate at middle, more closely at lateral sides; a minute tubercle present at base of elytral suture. Pygidium: opaque; minutely and sparsely punctate. Legs: protibiae quadridentate. Venter: metasternum finely and closely punctate with a fine median groove; lateral sides strongly but not closely punctate.

External male genitalia (Plate No. 10: Fig. 31 b)

Phallobase twice as long as parameres; parameres broad at base tapered distally and curved at lower side with tips acutely pointed and directed at front.

***Onthophagus (Colobonthophagus) ramosus* (Wiedemann, 1823)**

(Plate No. 10: Fig. 32 a, b)

Copris ramosus Wiedemann, 1823, 2, (1): 13 - Arrow, 1931, III: 229, 236, pl. 12, fig. 6, 7 - Krajcik, 2006: 128.

Onthophagus (Onthophagus) ramosus, Balthasar, 1963b, II: 497, fig. 204; *Onthophagus (Colobonthophagus) ramosus*, Löbl, Krell, Ziani and Král, 2006, 3: 163.

Diagnostic characters

Colour: indigo black; antennal club black; tarsi dark red; dorsally glabrous; ventrally with very short, sparse and yellow hairs. Shape: oval and moderately convex. Head: entirely rugose, clypeal margin rounded, reflexed; genae slightly angulate; clypeofrontal carina feebly rounded; vertex with a pair of backwardly directed horns, united by a strong carina with a short tubercle in middle. Pronotum: strongly and closely punctate; anterior and lateral punctures become slightly coarse; front angles blunt, strongly produced; lateral angles and base gently rounded. Elytra: finely striate; intervals finely and sparsely punctate in middle, slightly coarsely at lateral sides; 7th elytral stria almost parallel with 6th. Pygidium: finely punctate. Legs: protibiae quadridentate with serration at lower side. Venter: metasternum with a fine median groove, smooth in middle, closely punctate in front, lateral side finely punctate with very few yellow hairs; profemora with few coarse punctures; meso and meta femora finely and closely punctate; abdomen impunctate.

External male genitalia (Plate No. 10: Fig. 32 b)

Phallobase longer than parameres; parameres broad at base, tapered distally, with apical part curved ventrally and tips sharply pointed.

***Onthophagus (Colobonthophagus) ramosellus* Bates, 1891**

(Plate No. 11: Fig. 33 a, b)

Onthophagus ramosellus Bates, 1891, XXIV: 11 - Boucomont and Gillet, 1921, IV: 51 - Arrow, 1931, III: 210, 217 - Löbl, Krell, Ziani, and Král, 2006, 3: 175 - Krajcik, 2006: 128.
Onthophagus capella, Hope, 1831, 1: 22.
Onthophagus (Onthophagus) ramosellus, Balthasar, 1963b, II: 496.
Onthophagus (Colobonthophagus) ramosellus, Kabakov, 2006: 162.

Diagnostic characters

Colour: piceous and opaque dorsally; shining ventrally; antennal club yellow; completely devoid of hairs. Shape: oval and convex. Head: clypeus rugose, separated from frons by a curved clypeofrontal carina, a tubercle present behind it; vertex with a pair of horns. Pronotum: front angles bluntly produced; lateral sides and base rounded. Elytra: strongly punctate striate; intervals minutely and sparsely punctate, more closely and strongly at lateral sides; 7th stria almost parallel to 6th. Pygidium: opaque and finely punctate. Venter: metasternum finely punctate with a fine median longitudinal groove, more strongly punctate at lateral side.

External male genitalia (Plate No. 11: Fig. 33 b)

Phallobase more than twice in length as parameres; parameres a little broad at base, slightly tapered distally; apical part strongly curved ventrally with tips acutely pointed.

***Onthophagus (Colobonthophagus) quadridentatus* Fabricus, 1798**

(Plate No. 11: Fig. 34 a, b)

Copris quadridentatus Fabricius, 1798: 34.
Copris quadricornis, Fabricius, 1801, I: 54.
Onthophagus moerens, Walker, 1858, (3), II: 209.
Onthophagus quadridentatus, Arrow, 1931, III: 279, 282 - Löbl, Krell, Ziani, and Král, 2006, 3: 175 - Krajcik, 2006: 128.
Onthophagus (Onthophagus) quadridentatus, Balthasar, 1963b, II: 494

Diagnostic characters

Colour: piceous and shining; antennal club dark yellow; tarsi dark red; dorsally devoid of hairs; ventrally with very sparse hairs. Shape: oval and convex. Head: clypeal margin rounded, separated from frons by a clypeofrontal carina; genae rounded. Pronotum: finely punctate; front margin blunt, lateral angles and base rounded. Elytra: strongly striate; intervals finely and sparsely punctate. Pygidium: opaque, finely and sparsely punctate. Venter: metasternum finely and sparsely punctate with a faint median line, lateral side more strongly punctate. Legs: protibiae quadridentate.

External male genitalia (Plate No. 11: Fig. 34 b)

Phallobse twice as long as parameres; parameres flat and quadrate in shape; in lateral view apical portion protruded into a pointed process in lower side.

Subgenus *Matashia* Matsumura, 1938

Type species *Onthophagus yubarinus* Matsumara, 1938, 11(4):169

Diagnostic characters

Shining black with head, pronotum and ventral surface metallic black; elytra finely striated and weekly punctuate but the lateral margins of elytra are very well punctured. Head is flat and broad with reddish front margin; clypeus little produced and separated from head by a little carina. Pronotum is weekly but unevenly punctate; front angles rather blunt; lateral margins are curved in front, sinuate behind, and base is angulate. Elytra is finely striate and intervals slightly convex and rather finely but unevenly punctate. Pygidium is closely but unevenly punctate.

Onthophagus (Matashia) kuluensis Bates, 1891

(Plate No. 11: Fig. 35 a, b)

Onthophagus (Matashia) kuluensis Bates, 1891, XXIV:12 -Arrow, 1931, III: 292, fig. 35

Diagnostic characters

Colour: shining black with head, pronotum and ventral surface metallic black; elytra finely striated and weekly punctute but the lateral margins of elytra are very well punctured. Femora, antennal club, mouthparts, pygidium, and sides of abdomen reddish black; Shape: oval and moderately convex. Head: flat and broad with reddish front margin; clypeus little produced and separated from head by a little carina. Pronotum: weekly but unevenly punctate; front angles rather blunt; lateral margins are curved in front, sinuate behind, and base is angulate. Elytra: finely striate; intervals slightly convex and rather finely but unevenly punctate. Pygidium: closely but unevenly punctate. Venter: metasternum with fine punctures, but not very numerous.

External male genitalia (Plate No. 11: Fig. 35, b)

Phallobase, a little longer than parameres. Parameres broad at base, slightly tapered distally and curved ventrally with tips blunt with curved membranous plate on dorsal side**.**

Subgenus *Indonthophagus* Kabakov, 2006

Type species: unknown

Diagnostic characters

More or less black, pronotum; oval and moderately convex. Head is broad and flatclypeus separated from forehead by a carina. Pronotum is closely punctate and base rounded. Elytra is finely striate. Pygidium is closely punctate.

Identification key to the species of Subgenus *Indonthophagus*

1. Elytral intervals flat and dorsally weekly punctate while lateral strongly punctuate..
..................***Onthophagus (Indonthophagus) hastifer*** **Lansberge, 1885**
2. Elytral intervals minutely granulate ....
.................***Onthophagus (Indonthophagus) mopsus*** **(Fabricius, 1792)**

Onthophagus (Indonthophagus) hastifer **Lansberge, 1885**

(Plate No. 11: Fig. 36 a, b)

Onthophagus (Indonthophagus) hastifer Lansberge, 1885, 380- Arrow, 1931, III: 330
Onthophagus turmalis Gillet, 1924, XIIV: 66

Diagnostic characters

Colour: head is reddish black, pronotum comparatively shining black and ventral surface reddish brown; elytra is reddish black while posterior margin is reddish; antennal club, mouthparts yellow, femora, pygidium and sides of abdomen are reddish brown; ventral surface reedish brown thinly clothed with minute yellow setae. Shape: oval and moderately convex. Head: broad; clypeus separated from forehead by a carina. Pronotum: strongly very closely evenly punctate; front angles rather sharp; lateral margins straight in front, sinuate behind, and base rounded. Elytra: finely striate; intervals flat and dorsally weekly punctate while lateral strongly punctuate. Pygidium: closely punctate. Venter: metasternum with a very few punctures.

External male genitalia (Plate No. 11: Fig. 36 b)

Phallobase more than twice in length as parameres; parameres broad at base, slightly tapered distally with apical part obliquely placed ventrally with tips pointed and upward facing.

Onthophagus (Indonthophagus) mopsus **(Fabricius, 1792)**

(Plate No. 12: Fig. 37a, b)

Scarabaeus mopsus Fabricius, 1792, I: 58.
Copris mopsus, Fabricius, 1801, I: 49.
Copris gracilicornis, Germer, 1813, I: 114.
Onthophagus gracilicornis, Boucomont, 1914, XLVI: 220.
Onthophagus mopsus, Arrow, 1931, III: 327, 328 - Löbl, Krell, Ziani, and Král, 2006, 3: 175 - Krajcik, 2006: 119.
Onthophagus (Onthophagus) mopsus, Balthasar, 1963b, II: 441.

Diagnostic characters

Colour: blackish brown with slight metallic green lustre; dorsally closely clothed with minute setae. Shape: oval and convex. Head: clypeus rugosely punctate, strongly rounded in front and reflexed; clypeofrontal carina small and rounded; vertex smooth. Pronotum: very finely and closely punctate; front angles fairly sharp; lateral sides nearly straight in front, feebly sinuate behind; base gently rounded. Elytra: finely striate; intervals minutely granulate. Pygidium: strongly punctate. Legs: protibiae quadridentate with teeth small and blunt. Venter: metasternum sparsely punctate in middle with a slight median groove, strongly but sparsely at lateral side.

External male genitalia (Plate No. 12: Fig. 37 b)

Phallobase a little longer than parameres; parameres broad at base, slightly tapered distally with apical part obliquely placed ventrally with tips pointed and a membranous plate on dorsal side.

Subgenus *Phanaeomorphus* Balthasar, 1935

Type species: *Onthophagus sycophanta* Fairmaire, 1887, 31: 136

Diagnostic characters

Colour: shining black in colour. Clypeus produced strongly punctate. Pronotum strongly not very closely punctate dorsally and strongly and closely punctate at lateral sides. Elytra is finely striate. Pygidium is closely punctate above but sparsely punctate below.

***Onthophagus (Phanaeomorphus) gagates* Hope, 1831**

(Plate No. 12: Fig. 38 a, b)

Onthophagus (Phanaeomorphus) gagates Hope, 1831, 22- Arrow, 1931, III: 277, pl. 12 fig. 13, 14

Onthophagus angulatus Redtenbacher, 1848, IV (2)522, pl. 24 fig. 6

Diagnostic characters

Colour: shining black, head and sides of pronotum greenish black, lateral margin with three red spots in male while five red spots in female; elytra; femora, antennal club, mouthparts, pygidium, and sides of abdomen black; ventral surface thinly clothed with long yellow setae. Shape: oval and moderately convex. Head: triangular in male, flat rather broad in female; clypeus produced strongly punctate. Pronotum: strongly not very closely punctate dorsally and strongly and closely punctate at lateral sides; front angles rather sharp; marginated, sparsely sinuate, and base rounded. Elytra: finely striate; intervals slightly convex and rather finely but unevenly punctate. Pygidium: closely punctate above but sparsely punctate below. Venter: metasternum strongly punctuated along the sides.

External male genitalia (Plate No. 12: Fig. 38 b)

Phallobase almost thrice in length as parameres. Parameres broad at base strongly and regularly tapered distally slightly curved ventrally with pointed tips. Membranous plate on dorsal side conical in middle.

Subgenus Serrophorus Balthasar, 1935

Onthophagus Subgenus *Serrophorus* Balthasar, 1935, VIII: 306; Paulian, 1945: 86; Balthasar, 1963, II: 160.

Type species: *Onthophagus seniculus* Balthasar, 1963

Diagnostic characters

Antennal base serrated on the outer margin; protibia not stongly extended and curved in male. genae rounded at sides, not projecting much in front of eyes; clypeus little produced with its margin strongly reflexed and straight in middle.

Onthophagus (Serrophorus) rectecornutus **Lansberge, 1883**

(Plate No. 12: Fig. 39)

Onthophagus (Serrophorus) rectecornutus Lansberge, 1883, V: 49- Arrow, 1931, III: 233, fig. 24
Onthophagus (Serrophorus) rectecornutus, Balthasar, 1963, II: 498

Diagnostic characters

Colour: brownish yellow, pronotum is more blackish; femora, antennal club, mouthparts, pygidium, and sides of abdomen yellow; dorsal surface thinly clothed with minute yellowish grey setae. Shape: oval and moderately convex. Head: genae rounded at sides, not projecting much in front of eyes; clypeus little produced with its margin strongly reflexed and straight in middle. Pronotum: strongly not very closely but unevenly punctate; front angles rather sharp; sides rounded and base rounded. Elytra: finely striate; intervals rather finely but sparsely punctate. Pygidium: strongly not closely punctate. Venter: metasternum with fine punctures but not very numerous.

Subgenus *Palaeonthophagus* Zunino, 1979

Type species: *Onthophagus furciceps* Marseul, 1869:379

Diagnostic characters

Colour: black with yellowish lustre, sides of the pronotum and ventral surface is also yellowish; elytra sparsely striate, oval and moderately convex. Head is comparatively short and wider clypeus little produced and has clypeo-frontal carina. Pronotum is convex and slightly sinuate in female. Elytra is finely striated. Pygidium is strongly punctate.

Species **Onthophagusincertaesedis** genus *Onthophagus*

Identification key to the species of genus *Onthophagus*

1. 7th elytral stria straight and parallel with 6th stria………....***Onthophagus (Onthophagus) compactus*** **Arrow, 1933**

\- 7th elytral stria strongly curved than 6th stria **2**

2. Punctures of pronotum large, close and umblicate……………................***Onthophagus furcillifer*** **Bates, 1891**

3. Pronotum unequally and unevenly punctate…………………………………………………………………

   …..…………***Onthophagus (Onthophagus) cervus*** **(Fabricius, 1798)**

4. Pronotum finely punctate………………………………………….……

   ………..…..***Onthophagus (Onthophagus) griseosetosus*** **Arrow, 1931**

5. In males, vertex with a short, backwardly directed horn at posterior region of head, pronotum not vertical without any tubercle but with slightly hollowed in middle; in females, vertex with a conical tubercle in middle..***Onthophagus abreui*** **Arrow, 1931**

Onthophagus (Onthophagus) compactus Arrow, 1933

(Plate No. 12: Fig. 40)

Onthophagus compactus Arrow, 1933, 10, XII: 421 - Löbl, Krell, Ziani, and *Král*, 2006, 3: 174 - Krajcik, 2006: 97.

Onthophagus solidus, *Arrow*, 1931, III: 263, 265.

Onthophagus (Onthophagus) compactus, *Balthasar*, 1963b, II: 315.

Diagnostic characters

Colour*:* piceous and shining; pronotum and head with metallic lustre; dorsal surface with very fine setae; ventral surface, legs and metasternum with slightly long hairs. Shape: oval, deeply waisted and convex. Head: clypeal margin slightly excised, rugosely punctate, separated by a curved clypeofrontal carina from highly punctate frons; a straight carina present between eyes at posterior; genae rugopunctate not separated from clypeus. Pronotum: closely and strongly punctate; front angles sharp; lateral side and base rounded. Elytra: finely striate; 7th stria parallel with 6th; intervals finely and sparsely punctate. Pygidium: closely punctate. Venter: metasternum with a few large punctures in middle; lateral side with more punctures. Legs: protibiae quadridentate.

Onthophagus furcillifer Bates, 1891

(Plate No. 12: Fig. 41 a, b)

Onthophagus furcillifer Bates, 1891, 24: 11 - Arrow, 1931, III: 270, 273 - Löbl, Krell, Ziani, and Král, 2006, 3: 174 - Krajcik, 2006: 105.
Onthophagus (Onthophagus) furcillifer, Balthasar, 1963b, II: 360.

Diagnostic characters

Colour: piceous; anterior part of pronotum slightly coppery; antennal club and mouthparts yellow; dorsally and ventrally clothed with very minute setae. Shape: oval and convex. Head: clypeus short, rounded, finely punctate and feebly emarginate in front, separated by a strongly curved clypeofrontal carina; frons smooth; genae rugopunctate not separated from clypeus. Pronotum: evenly and closely punctate with large annular punctures; punctures umblicate with a granule in middle; front margin smooth, vertical in front with four tubercles, two inner ones joined; front angles blunt; lateral angles rounded; base slightly angulate in middle. Elytra: strongly striate; intervals with minute scattered granules. Pygidium: shallowly punctate.

Venter: metasternum strongly but sparsely punctate, lateral sides closely punctate. Legs: protibiae quadridentate.

External male genitalia (Plate No. 12: Fig. 41 b)

Phallobase more than thrice in length as parameres; parameres broad at base, sharply tapering distally, curved ventrally with tips very acutely pointed in middle at lower side in lateral view.

***Onthophagus cervus* (Fabricius, 1798)**

(Plate No. 13: Fig. 42 a, b)

Copris cervus Fabricius, 1798: 31.
Copris corvus, Fabricius, 1798: 31 (incorrect original spelling).
Onthophagus nuchidens, Fabricius, 1798: 31.
Onthophagus ceylonicus, Harold, 1877, X: 61.
Onthophagus cervus, Boucomont, 1914, 46: 227 - Arrow, 1931, III: 328, 348, fig. 45 -
Löbl, Krell, Ziani, and Král, 2006, 3: 175.
Onthophagus (Onthophagus) cervus, Balthasar, 1963b, II: 307.

Diagnostic characters

Colour: shining black with head, pronotum and ventral surface greenish black; elytra decorated with orange band, forming a broad external margin, extending almost to suture posteriorly, but generally irregular, and only reaching 4th elytral interval basally, lateral margin sometimes interrupted on 7th interval or wanting in middle; sometimes only irregular humeral and apical spots present; femora, antennal club, mouthparts, pygidium, and sides of abdomen yellow; dorsal surface thinly clothed with minute yellow setae. Shape: oval and moderately convex. Head: genae rounded at sides, not projecting much in front of eyes; clypeus little produced with its margin strongly reflexed and straight in middle. Pronotum: strongly not very closely but unevenly punctate; front angles rather sharp; lateral margins straight in front, sinuate behind, and base rounded. Elytra: finely striate; intervals slightly convex and rather finely but unevenly punctate. Pygidium: closely but unevenly punctate. Venter: metasternum with a very few fine punctures, at lateral sides punctures large but not very numerous.

External male genitalia (Plate No. 13: Fig. 42 b)

Parameres almost equal in length as phallobase; parameres bent at apical end and protrudes into a long and finger like process.

***Onthophagus griseosetosus* Arrow, 1931**

(Plate No. 13: Fig. 43)

Onthophagus griseosetosus Arrow, 1931, III: 184, 192 - Löbl, Krell, Ziani, and Král, 2006, 3: 174 - Krajcik, 2006: 108.
Onthophagus (Onthophagus) griseosetosus, Balthasar, 1963b, II: 374.

Diagnostic characters

Colour: black; elytra and pronotum opaque; head and ventrally shining; antennal club dark yellow; tarsi dark brown; dorsally clothed with dense yellow hairs; ventral surface and pygidium sparsely hairy. Shape: oval, long and deeply waisted. Head: clypeus rounded, reflexed at front margin, divided by a clypeofrontal carina from frons. Pronotum: closely packed with uniformly distributed oval granules; front angles blunt, a little produced; lateral sides rounded; base angulate in middle. Elytra: finely striate; intervals with numerous setigerous punctures. Pygidium: finely punctate. Legs:

protibiae quadridentate. Venter: metasternum smooth in middle, lateral sides rather closely punctate.

Onthophagus abreui Arrow, 1931

(Plate No. 13: Fig. 44 a, b)

Onthophagus abreui Arrow, 1931, III: 229, 239 - Löbl, Krell, Ziani, and Král, 2006, 3: 173 - Krajcik, 2006: 86.
Onthophagus (Onthophagus) abreui, Balthasar, 1963b, II: 260.*Onthophagus centricornis* (Fabricius, 1798)

Diagnostic characters

Colour: chocolate brown; pronotum, head and venter with greenish lustre; elytra opaque; antennal club yellow; tarsi dark red; dorsally clothed with small yellow setae, dense and long on ventral surface; pygidium with long hairs. Head: clypeal margin little reflexed; vertex with a horn (♂) or a tubercle (♀) in middle. Pronotum: finely and closely punctate; punctures becomes confluent at lateral sides; front angles sharp; lateral angles rounded; base angulate. Elytra: finely striate; intervals with many minute granules. Pygidium: strongly, not closely punctate. Legs: protibiae quadridentate. Venter: metasternum smooth in middle, lateral sides and base rather closely punctate.

External male genitalia (Plate No. 13: Fig. 44 b)

Phallobase longer than parameres; parameres broad at base, slightly tapered distally and apical part slightly curved ventrally with apex blunt.

Genus *Proagoderus* Lansberge, 1883

Onthophagus subgenus *Proagoderus* Lansberge, 1883b, V: 14 - Balthasar, 1963b, II: 156 - Löbl, Krell, Ziani, and Král, 2006, 3: 172**.**

Type species: *Onthophagus ritsemai* Lansberge, 1883.

Diagnostic characters

Large sized (11-20 mm long); brightly colored on dorsal surface, few species black; head and pronotum metallic; pronotum with very short inconspicuous setae while clypeus densely setose; pygidium with long dense hairs; base of pronotum strongly lobed in middle; clypeus rounded or parabolic at front; pronotum entirely closely granular; elytra narrow towards end; prosternum with a keel not reaching procoxae; metasternum vertical in front or with a keel; in males, protibiae elongate and toothed; pygidium margined.

Proagoderus pactolus (Fabricius, 1787)

(Plate No. 13: Fig. 45 a, b)

Scarabaeus pactolus Fabricius, 1787, I: 12 - Olivier, 1789, I, 3: 119, pl. 16, fig.144.

Onthophagus pactolus, Harold, 1867a, II (3): 39 - Boucomont, 1914, XLVI: 262 - Arrow, 1931, III: 203, pl. 1 fig. 11 - Krajcik, 2006: 123.

Proagoderus pactolus, Marcus, 1917, LXXXIII, A, 10: 65.

Onthophagus (Proagoderus) pactolus, Balthasar, 1963b, II: 466 - Löbl, Krell, Ziani, and Král, 2006, 3: 172.

Diagnostic characters

Colour: deep metallic green with sides of pronotum golden; venter entirely metallic green; elytra reddish orange with suture line and base dark green; antennal club yellow; tarsal segments dark brown; head, pygidium, sides of body and venter clothed with long yellow hairs; pronotum and elytra with short setae. Shape: narrowly oval and convex. Head: clypeal margin rounded and reflexed. Pronotum: closely and strongly punctate in middle; punctures become granules at lateral sides; anterior side smooth, shining and impunctate; front angles a little produced, lateral sides rounded; base strongly lobed. Elytra: very feebly striate; granulate uniformly. Pygidium: densely and closely punctate. Legs: protibiae quadridentate; meso and meta femora strongly punctate. Venter: metasternum strongly punctate.

External male genitalia (Plate No. 13: Fig. 45 b)

Phallobase almost thrice in length as parameres; parameres broad at base, with apical part tapered and strongly bent ventrally with tips bluntly pointed

Species identified upto subfamily level

Scarabaeinae sp. 1 **(Plate No. 14: Fig. 46)**

Scarabaeinae sp. 2 **(Plate No. 14: Fig. 47)**

Scarabaeinae sp. 3 **(Plate No. 14: Fig. 48)**

Scarabaeinae sp. 4 **(Plate No. 14: Fig. 49)**

Plate No.3

1 a

1 b

2 a

2 b

3 a

3 b

4 a

4 b

Fig. 1 a, b *Gymnopleurus cyaneus* Fabricius, 1798

Fig. 2 a, b *Paragymnopleurus sinuatus assamensis* Waterhouse, 1890

Fig. 3 a, b *Sisyphus (Sisyphus) longipes* (Olivier, 1789)

Fig. 4 a, b *Sisyphus (Sisyphus) neglectus* Gory, 1833

Plate No. 4

5 a

5 b

6 a

6 b

7 a

7 b

8 a

8 b

Fig. 5 a, b ***Catharsius pithecius*** **(Fabricius, 1775)**

Fig. 6 a, b ***Catharsius molossus*** **(Linnaeus, 1758)**

Fig. 7 a, b ***Catharsius sagax*** **(Quenselt, 1806)**

Fig. 8 a, b ***Copris repertus*** **Walker, 1858**

Plate No. 5

9

10

11 a

11 b

12 a

12 b

13

Fig. 9 ***Copris sarpedon*** **Harold, 1868**

Fig. 10 ***Copris (Paracopris) excisus*** **Waterhouse, 1891**

Fig. 11 a, b ***Copris (Paracopris) surdus*** **Arrow, 1931**

Fig. 12 a, b ***Tibiodrepanus setosus*** **(Wiedemann, 1823)**

Fig. 13 ***Euoniticellus pallipes*** **(Fabricus, 1781)**

Plate No. 6

14 a

14 b

15 a

15 b

16 a

16 b

17 a

17 b

Fig. 14 a, b ***Euoniticellus pallens*** **(Olivier, 1789)**
Fig. 15 a, b ***Oniticellus cinctus*** **(Fabricius, 1775)**
Fig. 16 a, b ***Liatongus gagatinus*** **(Hope, 1831)**
Fig. 17 a, b ***Liatongus mergacerus*** **(Hope, 1831)**

Plate No. 7

18 a

18 b

19 a

19 b

20

21 a

21 b

Fig. 18 a, b ***Liatongus phanaeoides*** **(Westwood, 1839)**

Fig. 19 a, b ***Tiniocellus spinipes*** **(Roth, 1851)**

Fig. 20 ***Onitis excavatus*** **Arrow, 1931**

Fig. 21 a, b ***Onitis falcatus*** **(Wulfen, 1786)**

Plate No. 8

22 a

22 b

23 a

23 b

24 a

24 b

Fig. 22 a, b ***Onitis philemon*** **Fabricius, 1801**

Fig. 23 a, b ***Onitis subopacus*** **Arrow, 1931**

Fig. 24 a, b ***Onitis virens*** **Lansberge, 1875**

Plate No. 9

25 a

25 b

26

27 a

27 b

28

Fig. 25 a, b ***Caccobius (Caccobius) denticollis*** **Harold, 1867**

Fig. 26 ***Caccobius (Caccophilus) diminutivus*** **Walker, 1858**

Fig. 27 a, b ***Caccobius (Caccophilus) unicornis*** **(Fabricius, 1798)**

Fig. 28 ***Cleptocaccobius inermis*** **(Arrow, 1931)**

Plate No. 10

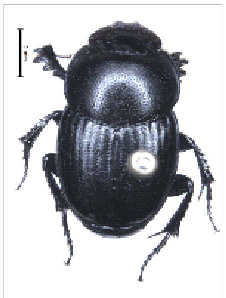
29 a

29 b

30 a

30 b

31 a



31 b

32 a

32 b

Fig. 2 9 a, b *Digitonthophagus bonasus* (Fabricius, 1775)

Fig. 30 a, b *Onthophagus (Colobonthophagus) dama* (Fabricius, 1798)

Fig. 31 a, b *Onthophagus (Colobonthophagus) hindu* Arrow, 1931

Fig. 32 a, b *Onthophagus (Colobonthophagus) ramosus* (Wiedemann, 1823)

Plate No.11

33 a

33 b

34 a

34 b

35 a

35 b

Fig. 33 a, b *Onthophagus (Colobonthophagus) ramosellus* Bates, 1891

Fig. 34 a, b *Onthophagus (Colobonthophagus) quadridentatus* Fabricus, 1798

Fig. 35 a, b *Onthophagus (Matashia) kuluensis* Bates, 1891

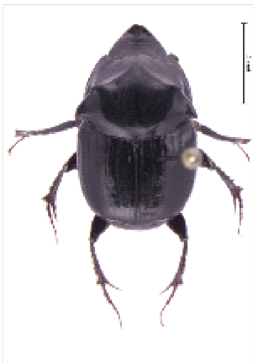
Fig. 36 a, b *Onthophagus (Indonthophagus) hastifer* Lansberge, 1885

Plate No. 12

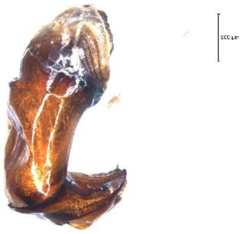
37 a

37 b

38 a



38 b



39

40

41 a

41 b

Fig. 37 a, b *Onthophagus (Indonthophagus) mopsus*(Fabricius, 1792)

Fig. 38 a, b *Onthophagus (Phanaeomorphus) gagates* Hope, 1831

Fig. 39 *Onthophagus (Serrophorus) rectecornutus* Lansberge, 1883

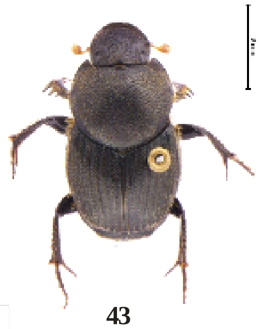
Fig. 40 *Onthophagus (Onthophagus) compactus* Arrow, 1933

Fig. 41 a, b *Onthophagus furcillifer* Bates, 1891

Plate No. 13

42 a

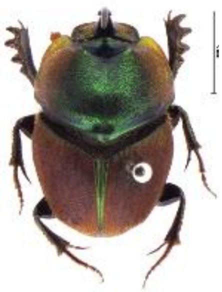
42 b



43

44 a

44 b



45 a

45 b

Fig. 42 a, b *Onthophagus cervus* (Fabricius, 1798)

Fig. 43 *Onthophagus griseosetosus* Arrow, 1931

Fig. 44 a, b *Onthophagus abreui* Arrow, 1931

Fig. 45 a, b *Proagoderus pactolus* (Fabricius, 1787)

Plate No. 14

46

47

48

49

Scarabaeinae sp. 1 **(Fig. 46)**
Scarabaeinae sp. 2 **(Fig. 47)**
Scarabaeinae sp. 3 **(Fig. 48)**
Scarabaeinae sp. 4 **(Fig. 49)**

CHAPTER 6

Assessment of bioindicator species

6.1 Introduction

Dung beetles as bio-indicator across landscape matrix have been used in empirical studies (Klein 1989; Davis et al. 2001, 2008; Gardner et al. 2008) to evaluate the biodiversity loss, forest fragmentation and the impact of habitat modification. The structure, organization and composition of guild structure of dung beetles primary forest are totally different from the fragmented forests and also a transition guild is also present in ecotones which have its own structure (Halffter & Favila 1993). Changes in dung beetle assemblage structure are correlated with climatic and/or edaphic variables, which clearly interact to drive biogeographical composition and population responses of dung beetle species across regional and local gradients.

Studies (Estrada et al. 1998; Numa et al. 2009, 2012; Shahabuddin et al. 2014; Batista et al. 2016) showed that the existence of a rich pool of forest dung beetles species exist in the fragmented landscape but the majority of the species are represented in low numbers. Species richness, abundance, and biomass declined drastically on smaller and more isolated islands (Larsen et al. 2008). Fragment characteristics such as vegetation structure, ground cover, litter depth, age, and isolation distance also influence dung beetle assemblage in forest. Due to the modification in tree cover or canopy cover, native forest species undergo local extinction and are replaced by open area species (Halffter & Arelleno 2002). Canopy cover is thought to be influence humidity as well as atmospheric and soil surface temperature, which might affect the survival and reproduction of dung beetles, as well as food availability and attractiveness.

Edge effects also considered as an important factor in the distribution and composition of dung beetles communities as abundance, species richness and species composition of dung beetles changed with distance from roads/trails Forest edges act as a barrier and affect the patterns of dispersal and spatial distribution of dung beetles communities. Narrow or small forest clearings for skid trails, logging roads, log yards, and logging camps affect local distributions of dung beetles. Litter has been reported to be important for modifying soil characteristics such as moisture, density, and nutrient load, which may increase the recruitment and/or reproduction of dung beetles.

Changes in land management practices such as pastures replaced by arboreal crops results the replacement of a rich assemblage of native species by introduced species just as *Digithonthophagus gazella*, a savanna specialist, that has been expanding its range southward from the United States in part as a result of conversion of large extension of rain forest to pastures (Montes De Oca & Halffter, 1998). Escobar et al. (2007) evaluated the effect of expanded cattle ranching along three altitudinal gradient in one located in the Mexican Transition Zone and two located in northern Andes. All three sites are facing immense pressure of not only dairy farming but also expansion of mountain into agricultural areas. They reported that processes of disturbance caused by human activity along altitudinal gradients can impact communities in different ways, depending on the geographic position of each mountain and particularly the biogeographical history of the group of species that inhabits it.

Drawing upon historical data, comparisons among dung beetle collections across parts of Africa and the Mediterranean provide circumstantial evidence of strong, linked changes in mammal-dung beetle assemblages, typically within a context of broader land-use change (Nichols et al. 2009). Lobo et al. (2002) also analyzed which factor or factors govern the species richness and distribution of dung beetles of France mainland and Corsica Island. Six climate variables were utilized mean annual temperature, temperature variation, maximum mean temperature, minimum mean temperature, mean annual precipitation and precipitation variation. Results showed that minimum mean temperature is the most influential variable on a local scale, while maximum and mean temperature are the most important spatially structured variables. There is evidence for a general increase in the temperature tolerance range of dung beetles across an elevational gradient of approximately 2500m a.s.l. in southern Africa. It was reflected in a shallow increase in the maximum thermal tolerance range exhibited at different elevations, and a steep increase in the minimum thermal tolerance range, and hence the reduced variance in tolerance ranges towards higher elevations Nonetheless, the overall pattern is one of increasing thermal tolerance range with elevation for dung beetles (Gaston & Chown 1999).

In Europe Menéndez et al. (2014) compared historical and current data on dung beetle distributions along elevation gradients for 30 species in the South-western Alps (France) and 19 species in the Sierra Nevada (Spain) and reported that up-slope range shifts for 63% and 90% of the species in the SW Alps and Sierra Nevada, respectively. The magnitudes of range shifts were consistent with the level of warming experienced in each region, but they also reflected the asymmetrical warming observed along the elevation gradients. This study reveals that climate change is directly or indirectly responsible for range-shift of the species.

Dung beetles was also used to assess the ecological restoration in tropical forest to understand the recovery of functional and species diversity. It was observed that that restored areas have the capacity to host forest-restricted species, but additional recovery time is likely needed to allow for the complete recovery of all biodiversity aspects (Audino et al. 2014). Anthropogenic land use and habitat fragmentation clearly promote community level taxonomic divergence in human modified landscapes. This community level taxonomic divergence suggests that edge-dominated and matrix habitats ensure the persistence of disturbance adapted species, some of which exclusively in these habitats, which are unsuitable for forest dependent species (Filgueiras et al. 2016).

The dung beetle community at Amakhala Game Reserve showed ecological partitioning based on the types of dung its members were attracted to. At the species level, of 43 species of dung beetles, seven showed specificity for a particular type of dung. In different dung beetle species, quality and quantity of dung available for larvae influence their size, time of development and survival rates, as well as the size, morphology and mass of the emerged adults (Tocco et al. 2018.). Hence these species must be successful bioindicator for ecological monitoring in the reserve. New paradigms in conservation biology propose that not only protected areas but also patches of natural habitat via corridors should be analyzed in the context of the agricultural or managed matrix. Land use patterns significantly affect the species assemblages, diversity, and richness and also guild structure across various habitats.

6.2 Methods

6.2.1 Specimen collection

Beetles were collected by the various sampling methods *viz*., hand sorting, pitfall trap and light trap as previously discussed (Section 3.8). Different habitat has been sampled (Appendix 6.1).

6.2.2 Data analysis

Important indicator species of dung beetles have been identified for each habitat type by using the indicator value (*IndVal*) method (Dufrene & Legendre 2007). Indicator value (*IndVal*) quantifies the fidelity and specificity of species in relation to groups of sites in a user-specified classification of sites, and tests for the statistical significance of the associations by permutation.

Specificity (A_{ij}) = N individuals_{ij} / N individuals_{i}

Where, N individuals_{ij} is the mean number of species across sites of group

And, N individuals_{i} is the sum of the mean numbers of individuals of species over all groups

Fidelity (B_{ij}) = N sites_{i} / N sites_{j}

Where, N sites_{i} is the number of sites in cluster (habitat) j where species i is present, and N sites_{j} is the total number of sites in that cluster.

The indicator value of species in cluster (habitat) $IndVal_{ij} = A_{ij} \times B_{ij} \times 100$

The indicator values was highest (100) when all individuals of a species are found in a single habitat (high specificity) and when the species occurs in all samples of that habitat (high fidelity). Species with between 50% to less than 75% is categorized as the indicator species while species with significant of greater than 75% will be regarded as characteristic indicator species for the particular habitat type.

Indval package in cran.r-project has been use for this analysis.

6.3 Results

Based on analysis of species collected in three sampling years during this study recorded eight species having more than 70% and therefore, can be used as indicator (characteristic) species of specific habitat and are suggested to be used as indicators of such habitat. These characteristic species ((*IndVal* of > 70%) are unlikely to move from their requisite to other habitat types, even under changing conditions within this habitat. Accordingly, populations of these species need only to be monitored within the specific habitat. Beside indicator species, this study has recorded several generalist or moderate species with between 50% to less than 70%. These species were therefore, not characteristic species, as they do not have high of more than 70% for any particular habitat.

Table No. 6.1 Indicator species analysis for habitat fiedelity

S. No.	Species	Habitat	Indval	pvalue	Elevation ranges
1	*Oniticellus cinctus*	Deodar Forest, Banj Oak Forest	0.841193	0.001	500-2000m a.s.l
2	*Onitis philemon*	Human Habitation, Agriculture	0.776853	0.005	500-1800m a.s.l.
3	*Onthophagus hastifer*	Human Habitation, Agriculture	0.834115	0.001	2500- 4000m a.s.l.
4	*Onthophagus dama*	Human Habitation	0.754768	0.007	1000-1700m a.s.l.
5	*Onthophagus gagates*	Mixed Forest	0.755302	0.001	1000-2500m a.sl.
6	*Onthophagus ramosellus*	Mixed Forest	0.810787	0.005	1000-2500m a.sl.
7	*Tibiodrepanus setosus*	Celtis, Mixed Forest	0.847184	0.001	500-2000m a.s.l
8	*Tiniocellus spinipes*	Celtis, Mixed Forest	0.810787	0.001	500-1800m a.s.l.

6.4 Discussion

I have identified eight indicator species of different habitat from the landscape (Table 6.1). *Onthophagus dama* has been identified as an indicator for human habitation at lower ranges from 1000-1700m a.s.l. This species is a tunneller and largely uses cattle dung for nestling and brood balls. High abundance has been observed in the landscape. *Onthophagus ramosellus* and *Onthophagus gagates* are identified as indicator of mixed forest upto mid elevation ranges at 1000-2500m a.sl. Both the species are tunneller building tunnel inside soil and using dung for making brood bolls. *Onthophagus hastifer* is identified as an indicator for human habitation and agriculture at high elevation from 2500- 4000m a.s.l. Which states that species is greatly contributing for dung removal in the lower elevation. *Tibiodrepanus setosus* is an indicator for Celtis and mixed forest at lower elevation upto 1500m a.s.l. *Oniticellus cinctus* is indicator for Deodar forest and Banj Oak forest upto 2000m a.s.l. and *Tiniocellus spinipes* for Celtis, mixed forest upto lower elevation from 500-1800m a.s.l. and *Onitis philemon* for human habitation and agriculture upto lower elevation from 500-1800m a.s.l.

So now I have indicator species for habitat and these species are restricted to a certain elevation range in the landscape hence they can be used in different area in different elevation. Since this study has been done for three years also taxonomy and community structure of different species are known from the landscape, we can use this as reliable baseline data for further climate change and habitat fragmentation studies in the landscape. The success of using dung beetles is based on cost-effective data collection, sensitivity to different environmental factors and wide habitat requirements. Same is true for dung beetles and these species meeting these criteria are unlikely to respond very rapidly to changing habitat conditions. Furthermore, these species are less likely to become more vulnerable than indicator species, because a variety of habitats or ecological states, rather than only a single one, provides suitable resources for them and accordingly this group of species will be useful for long-term monitoring.

Dung beetles follow peak activity period in monsoon season, Therefore, monitoring once a year during monsoon can reduce expenditure and improve the likelihood of support for a long monitoring programme. Ecological data on population structure, community composition, habitat specificity of dung beetles correlated with biogeographic and historical data can be efficient model to analyze the impact of human induced changes in forest along different land use gradient, climate change and forest fragmentation. We need long-term observations and basic ecological studies to assess the impact of land management practices in the landscape. Study demonstrates that such an approach is feasible in this context. This study highlights bioindicator based approach for long term ecological monitoring for this landscape, having matrix of protected areas, dominated agriculture system and patchy habitats particularly vulnerable for climate change and land use changes.

CHAPTER 7

Mapping of important dung beetles diversity rich areas (Maximum Entropy distribution modelling)

7.1 Introduction

Species distributions and relationships with associated habitats have typically been analysed using correlative models that use linear and logistical regressions to predict the main drivers of species abundance over the spatial and temporal scale. Recent advancements in open source software, using geographical information, permit to use known species presence (and absence) data in combination with environmental niche variables to more accurately model likely temporal and spatial changes for species. These models can help to assess all the possible species responses to climate change, anthropogenic disturbance, habitat destruction and forest fragmentation. They can also be used to forecast suitable species range shifts through estimations of the probability of presence given a series of biotic and/or abiotic variables such as terrain, habitat, elevation or other dispersal factors.

Dung beetles are widely distributed in the KSL, landscape. *Caccobius* and *Liatongus* genus were identified from 4000m a.s.l. range in the alpine meadows, while genus *Catharsius*, *Onitis*, *Oniticellus*, *Onthophagus*, *Sisyphus*, *Tiniocellus* were present upto mid altitude ranges. This landscape is highly vulnerable to climate change, forest fragmentation and habitat loss due to augmented land use practices. Hence the distribution of dung beetles will be likely to alter in near future which ultimately lead to change the community structure or functional diversity of the species in the landscape. Species entropy distribution modelling could predict the potential distribution ranges of the dung beetles. Two principal ecological factors influence present tribal, generic and species distribution patterns of dung beetles (scarabaeinae) at world-wide scale. These factors comprise a suitable climate and the number of dung types. Although microhabitat conditions also influence the distribution species at a local scale. At species and generic level, there is a strong correlation between dung beetle taxon richness and the area of suitable climate in each of the world's biogeographical regions (Davis et al. 2002).

Maxent (maximum entropy) is a robust algorithm which is suitable for presence-only data, as species absences are not available for all species and even more difficult to obtain for rare species (Philips et al. 2006, Hawlitschek 2011). It out-competes other algorithms by more accurately predicting occurrences that are represented by small data sets (Aguirre-Gutiérrez et al. 2013).

7.2 Methods

7.2.1 Specimen Collection and taxonomy

Dung beetles were collected by the various sampling methods *viz*., hand sorting, pitfall trap and light trap as previously discussed (Section 3.8). ARC GIS has been used to prepare the maps.

All the collected specimen have been identified on the basis of available taxonomic keys and male genitalia. Species with more than 70 presence records were taken into consideration for this study (Appendix 7.1). Tribe Onitini (*Onitis* genus), Sisyphini (*Sisyphus* genus), Onthophagini (*Caccobius*, *Onthophagus* genus) Coprini (*Catharsius* genus), Oniticellini (*Oniticellus*, *Tiniocellus*, *Liatongus* genus) were taken into account.

7.2.2 Data extraction and statistical analysis

To study the distribution of species from *Caccobius*, *Catharsius*, *Liatongus*, *Onitis*, *Oniticellus*, *Onthophagus*, *Sisyphus*, *Tiniocellus;* 43 environmental layers for temperature, precipitation, bioclimatic variables were downloaded from online sources (www.worldbioclim.org). The data for each point locality were extracted using ArcGIS software. Principal components analysis of the variance-covariance matrix was performed to extract the most significant factors, and the number of these factors was identified based on the scree plot. Squared cosine was calculated to know the contribution of each factor for a given variable (Table 7.1). Out of the total 43 significant layers, 6-bioclimatic with the resolution of the 30s were used for the modelling (extracted soil layers did not have similar resolution hence excluded). The selected layers were clipped for KSL in ASCII format at a resolution of 1 sq.km on WGS84 CRS system using ArcGIS software.

A separate .csv file for each species with its presence localities was prepared. The model was run with random test percentage as zero because of cross-validation run type was used to calculate real AUC value (real area under the ROC curve). The cross- validate replication run considers all the data for validation which is advantageous (Proosdij et al. 2016; Philips, 2017). Maximum iterations were kept at 500 with 10 convergence thresholds. Maximum iterations (repetitions) are steps taken to come and, convergence threshold is the probability of omitting actual presence (Jobe & Zank 2008). A total of 50 replications were run, and the average was used for analysis and interpretation. The model performance was evaluated based on AUC values (van Proosdij et al. 2016). The output was obtained in logistic format (default) and file type ASCII. The logistic output was obtained in the form of the response curve and predicted area of Occurrence with suitability values 0 (unsuitable) to 1 (suitable). The logistic format presents the probability of species occurrence in a suitable environment by comparing models of different spatial scales (Jobe & Zank 2008; Philips et al. 2006; Merow et al. 2013). Jack-knife of AUC was used to determine the effect of the environmental variable on each species studied. Jack-knife test evaluates the most important variables for species distribution. In the process, several models are built (1) excluding each variable, (2) using a single variable and (3) using all variables. The output of Jack-knifed environmental variables appears as a bar chart.

Table 7.1 Environmental layers used for predictive distribution modelling

Category	**Variables**	**Units**	**Time span**
Topography*	Altitude	m above asl	1900-2015
Bioclimate **	Temperature (Bio1-Bio11)	C*10	1895-2009
Bioclimate**	Precipitation (Bio12-Bio19)	Mm	1895-2009
Precipitation**	Monthly mean precipitation	Mm	1895-2009
Temperature**	Monthly mean temperature	C*10	1895-2009

Data information were downloaded from * webmap.ornl.gov, ** www.worldclim.org

7.3 Results

7.3. 1 Georeferenced environmental factors

Principal component analysis of 43 environmental layers extracted three factors based on eigenvalues which explained most of the variation in the data set (Table 7.1). Out of all these layers, temperature seasonality (primary important variable) had high squared cosine values for the first factor. Annual precipitation, precipitation of wettest month, precipitation of driest (secondary important variables) had high squared cosine values for the second factor. Precipitation of coldest quarter and Precipitation seasonality had high squared cosine values for the third factor.

7.3. 2 Area under the curve

The Area under the curve (AUC) values for all seventeen models (Fig.) were higher than 0.9 and hence have significant abilities for discrimination of presence from background data (Swets 1988). Therefore, any randomly chosen presence of a species is ranked higher than the background data (Merow et al. 2013) hence, the distribution models were considered useful.

The Jack-knife of AUC (Plate No. 15-33) for all sixteen models indicated temperature seasonality, Annual precipitation, precipitation of wettest month, precipitation of driest, Precipitation of coldest quarter and Precipitation seasonality were the most significant factors for their distribution. The logistic output for the significant factors is presented in Plate No.15-33.

7.3. 3 Response Curves

Precipitation (Plate No. 15-33)

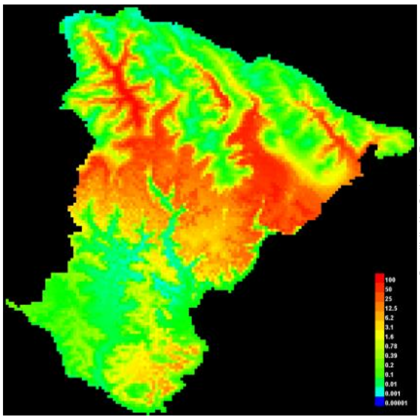
Catharsius molossus, Oniticellus cinctus showed similar trends of their predictive presence which was found between the region with precipitation of wettest month and precipitation seasonality. All the three *Onitis* species showed similar pattern for precipitation of coldest quarter and precipitation seasonality; similarly all three *Liatongus* species showed similar pattern for precipitation of driest month and annual precipitation. All *Sisyphus* and *Onthophagus* species showed similar trends for precipitation seasonality and precipitation of coldest quarter; where as *Caccobius (Caccobius) denticollis* and *Tiniocellus spinipes* showed similar trends for precipitation of coldest quarter, precipitation of driest month and precipitation seasonality. The probability of presence increased between 0-2000 mm precipitation of wettest month.

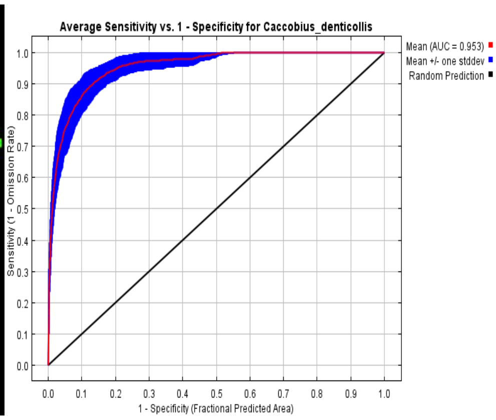
Temperature Seasonality (Plate No. 15-33)

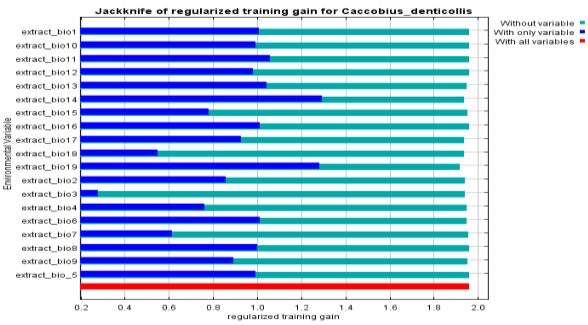
The temperature seasonality is the standard deviation of the average monthly temperature values multiplied by 100. The fluctuations in temperature affected the probability of the presence of *Caccobius*, *Catharsius*, *Onitis*, *Oniticellus*, *Onthophagus*, *Sisyphus*, *Tiniocellus* while *Liatongus*, had a negligible effect.

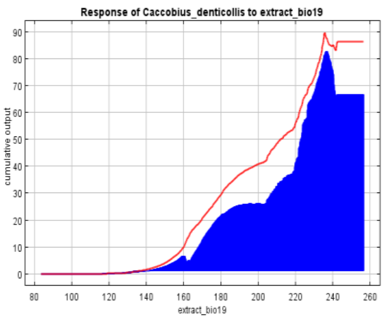
Plate No. 15

MaxEnt output, Jackknifed environmental variables; cumulative output for Precipitation of Coldest Quarter (Bio19) & Precipitation of Driest Month (Bio14) of *Cacobius denticolis* in KSL India.









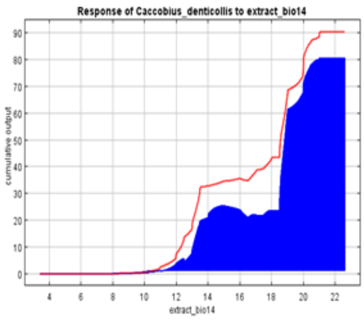
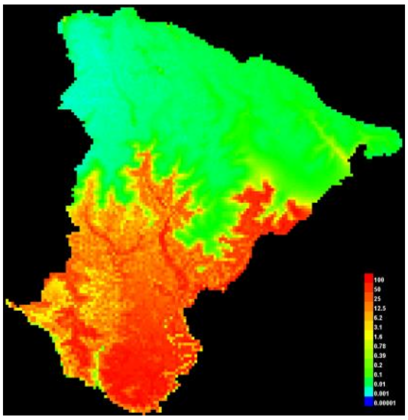
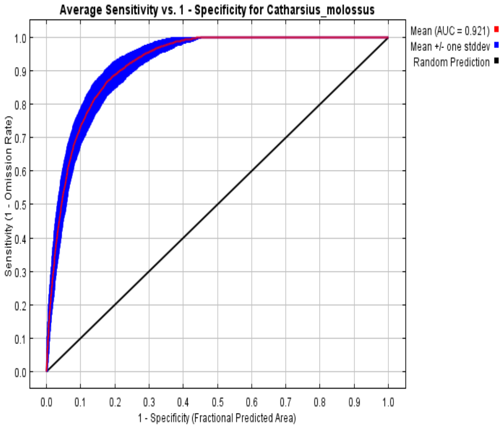
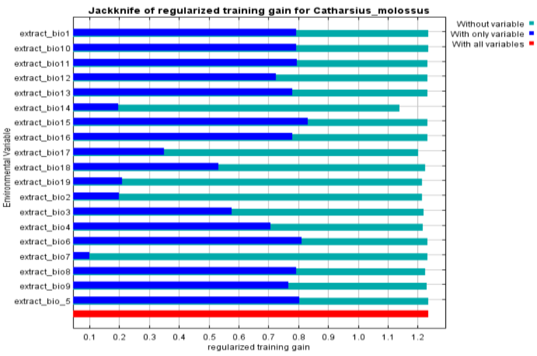


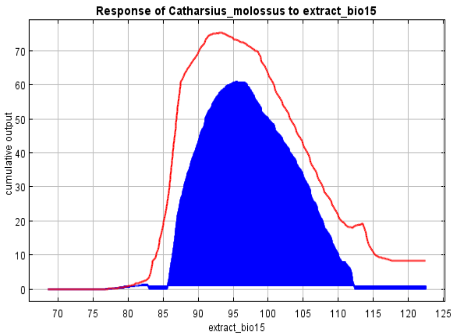
Plate No. 16

MaxEnt output, Jack-knifed environmental variables; cumulative output for Precipitation of Seasonality (Bio15) & Precipitation of Wettest Month (Bio13) of Catharsius molossus in KSL India.









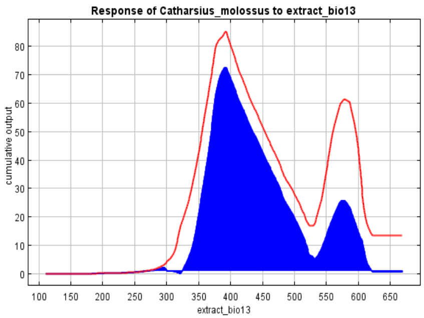
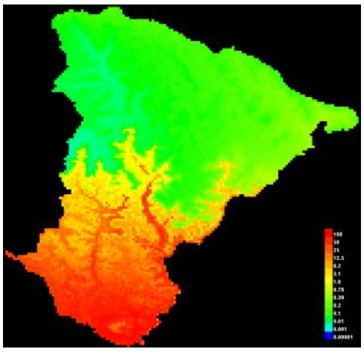
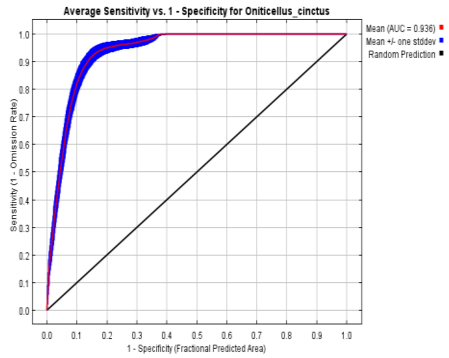
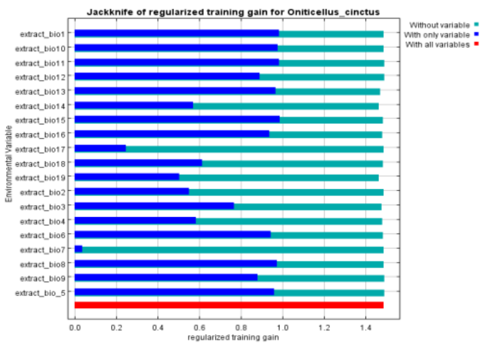


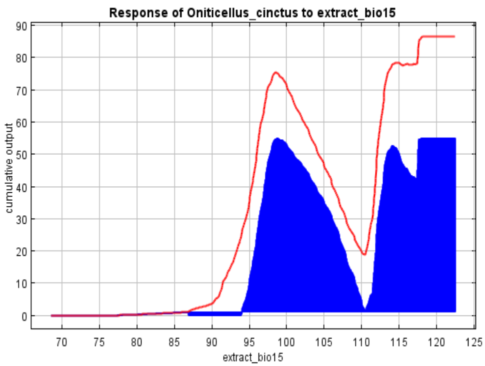
Plate No. 17

MaxEnt output, Jack-knifed environmental variables; cumulative output for Precipitation of Seasonality (Bio15) & Precipitation of Wettest Month (Bio13) of *Oniticellus cinctus* in KSL India.









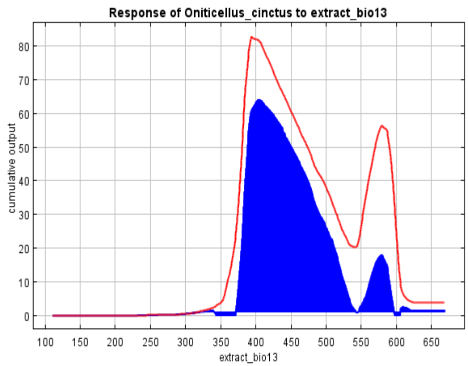
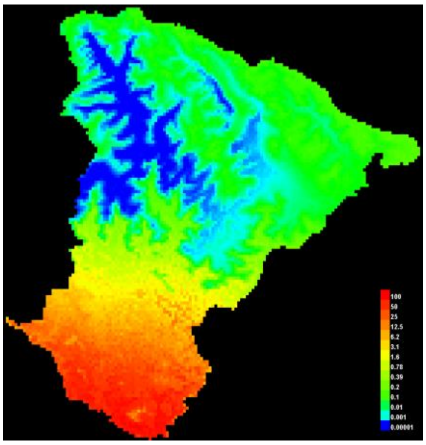
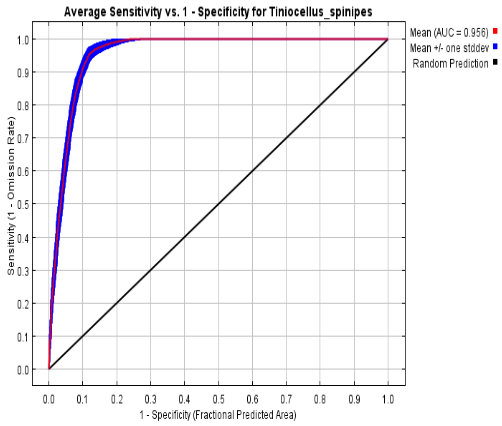
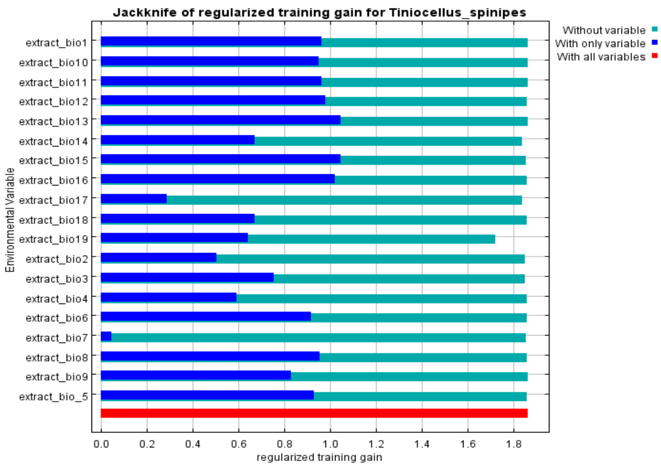


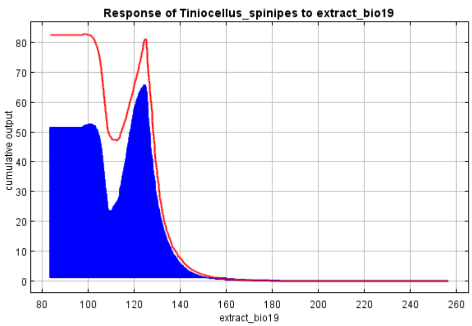
Plate No. 18

MaxEnt output, Jack-knifed environmental variables; cumulative output for Precipitation of Seasonality (Bio15) & Precipitation of Coldest Quarter (Bio19) of *Tiniocellus spinipes* in KSL India.









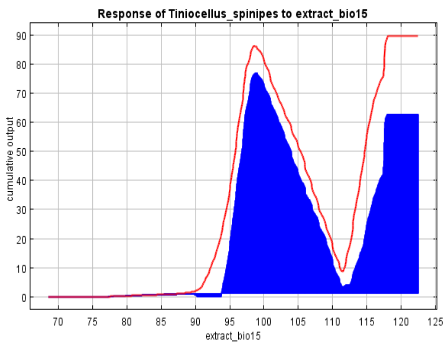
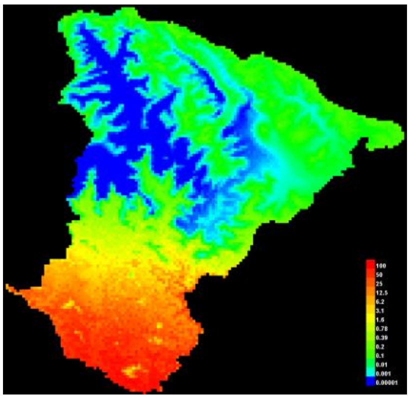
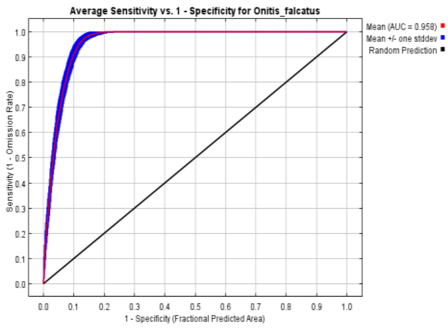
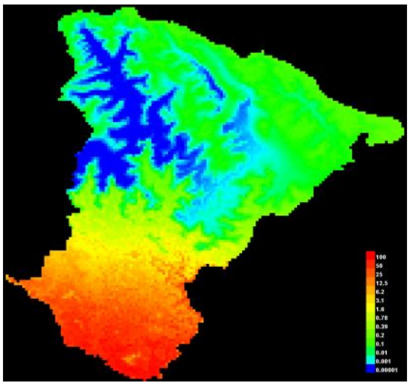


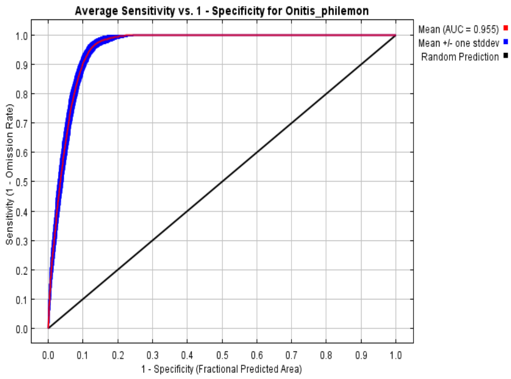
Plate No. 19

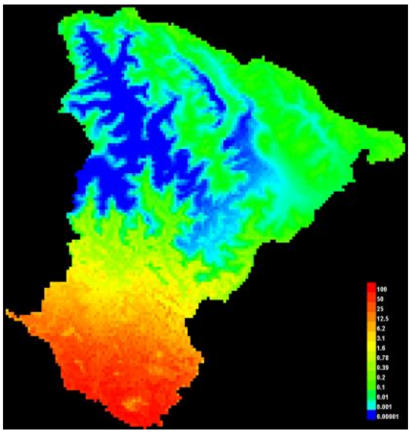
MaxEnt output of *Onitis falcatus*, *O. philemon* and *O. subopacus*, in KSL India.











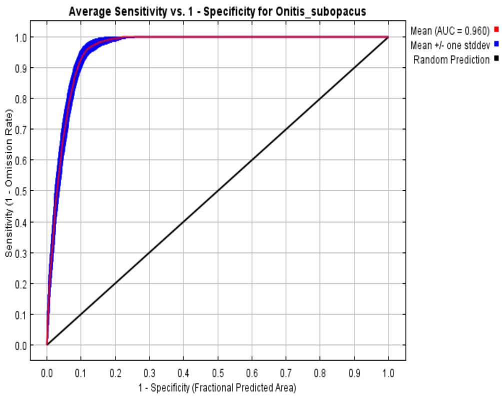


Plate No. 20

Jack-knifed environmental variables; cumulative output for Precipitation of Seasonality (Bio15) of *Onitis falcatus, O. philemon* and *O. subopacus* in KSL India.

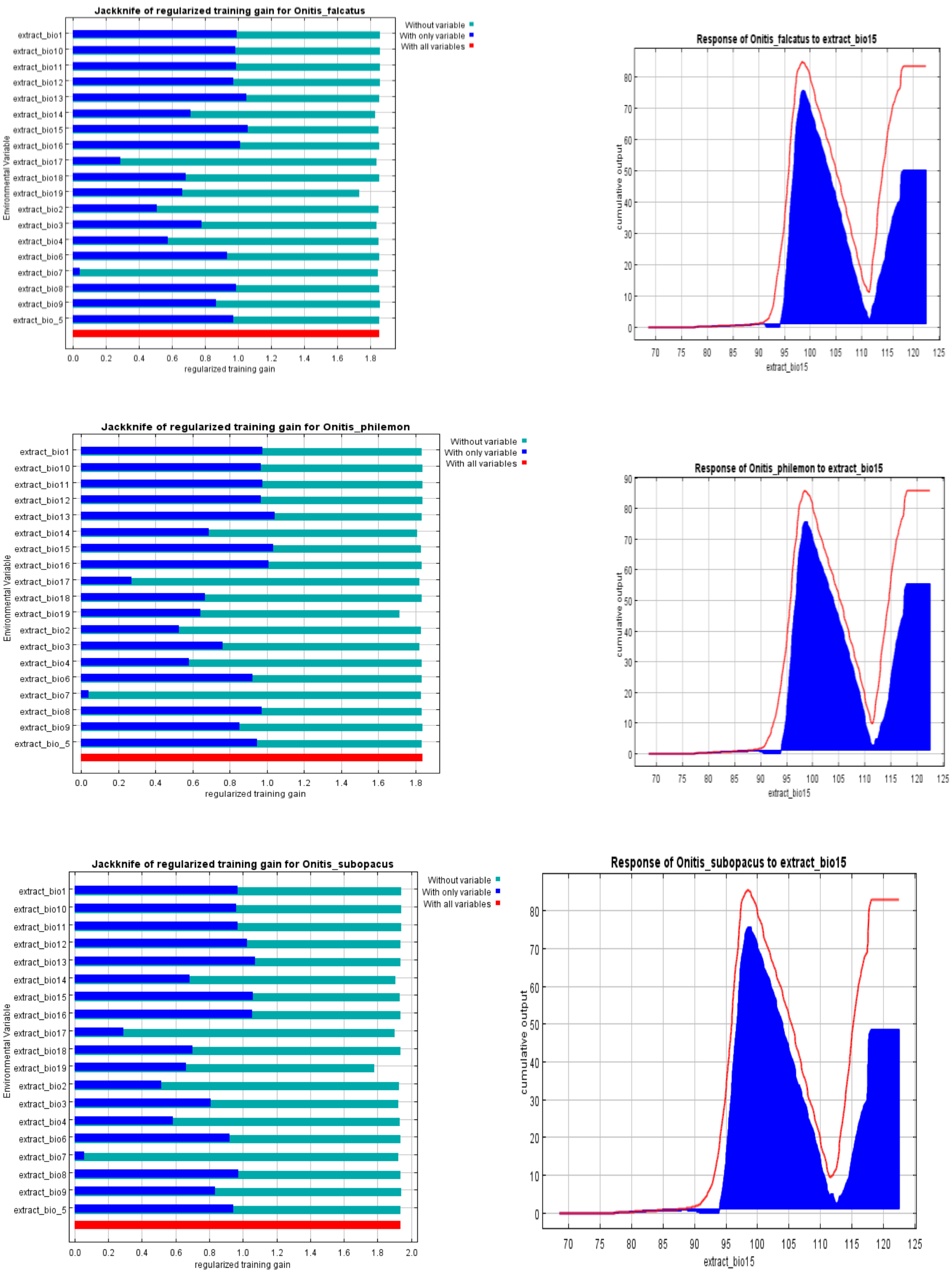


Plate No. 21

Cumulative output for Precipitation of Coldest Quarter (Bio19) & Annual precipitation (Bio12) of *Onitis falcatus*, *O. philemon* and *O. subopacus* in KSL India.

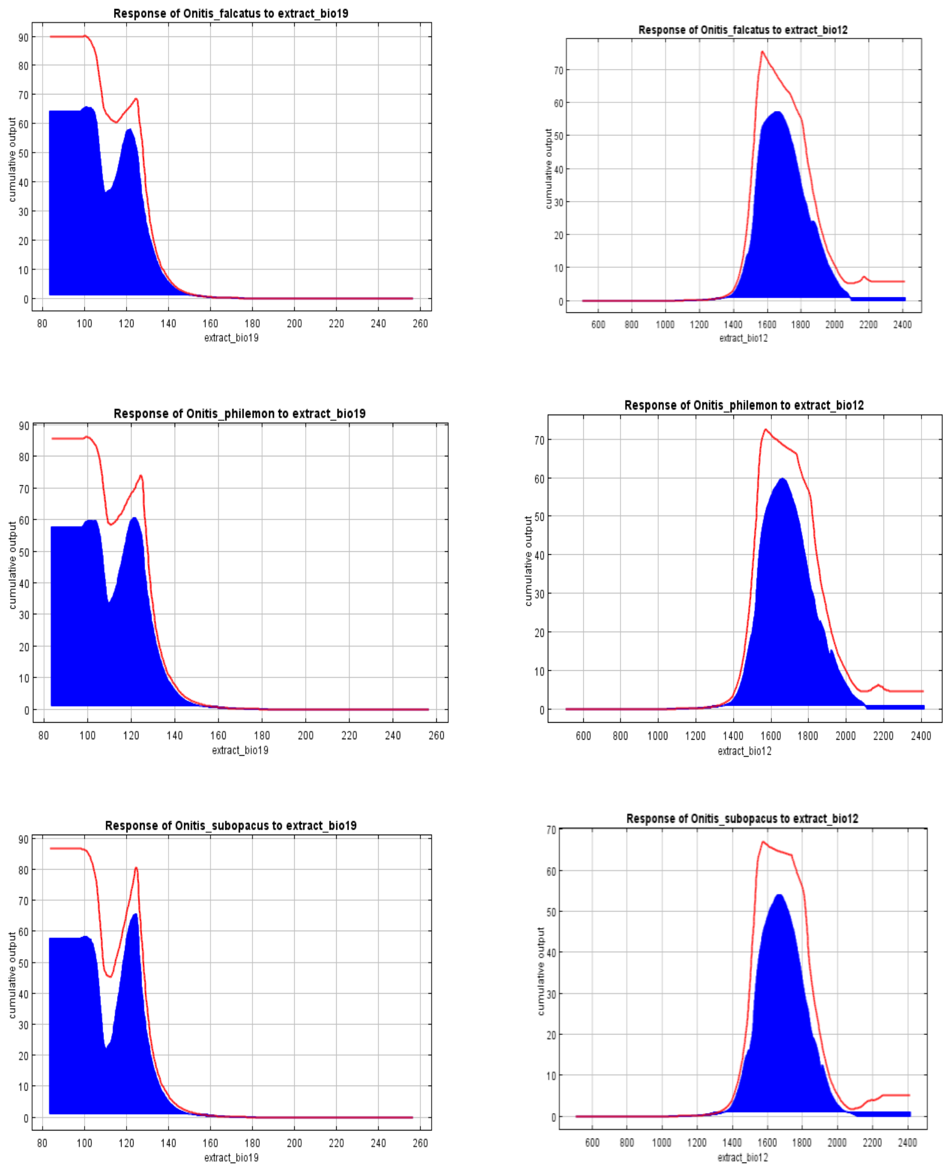


Plate No. 22

MaxEnt output of *Liatongus gagatinus*, *L. mergacerus* and *L. phanaeoides* in KSL India.

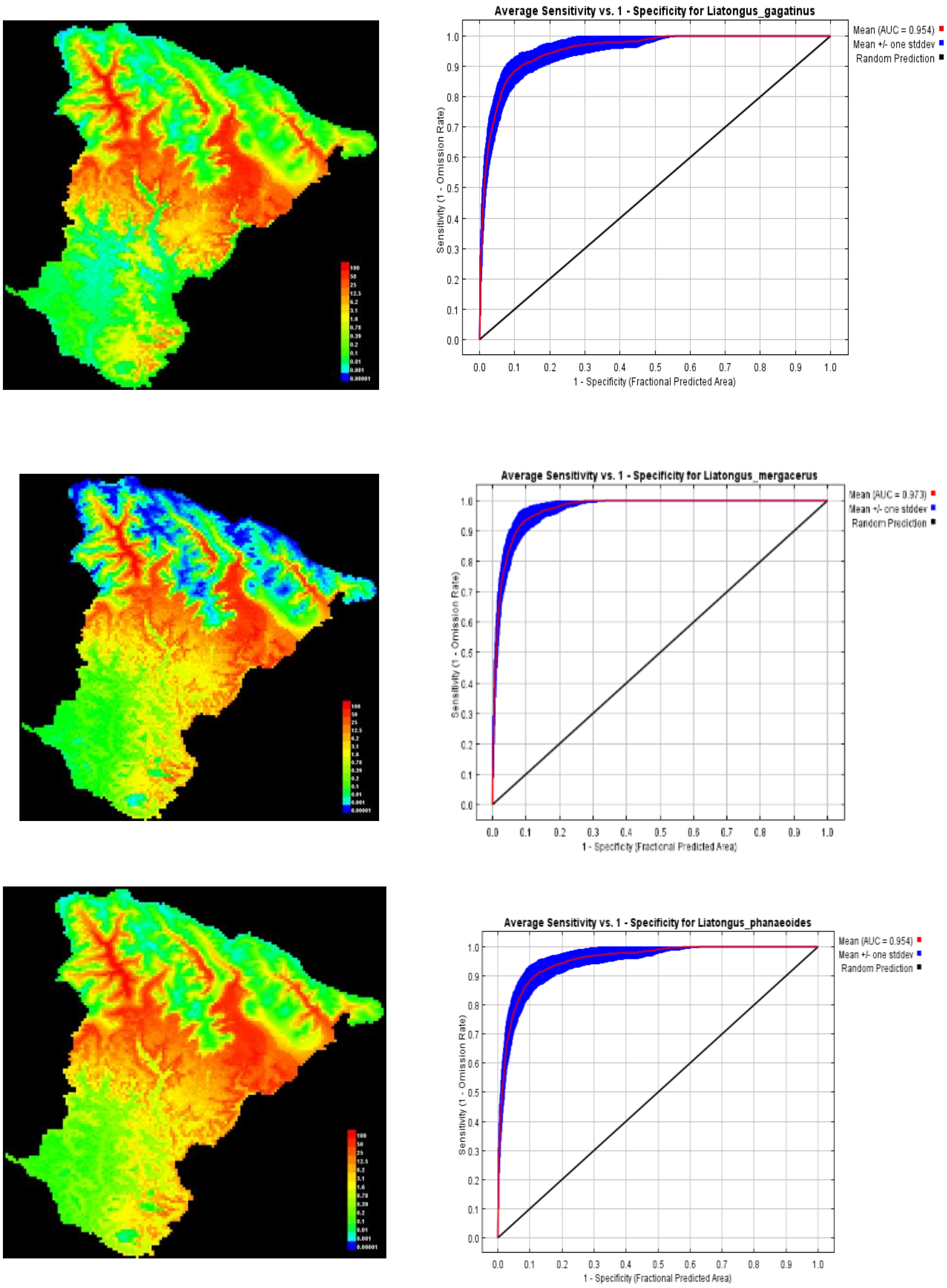


Plate No. 23

Jack-knifed environmental variables; cumulative output for Precipitation of Seasonality (Bio2) of *Liatongus gagatinus*, *L. mergacerus* and *L. phanaeoides* in KSL India

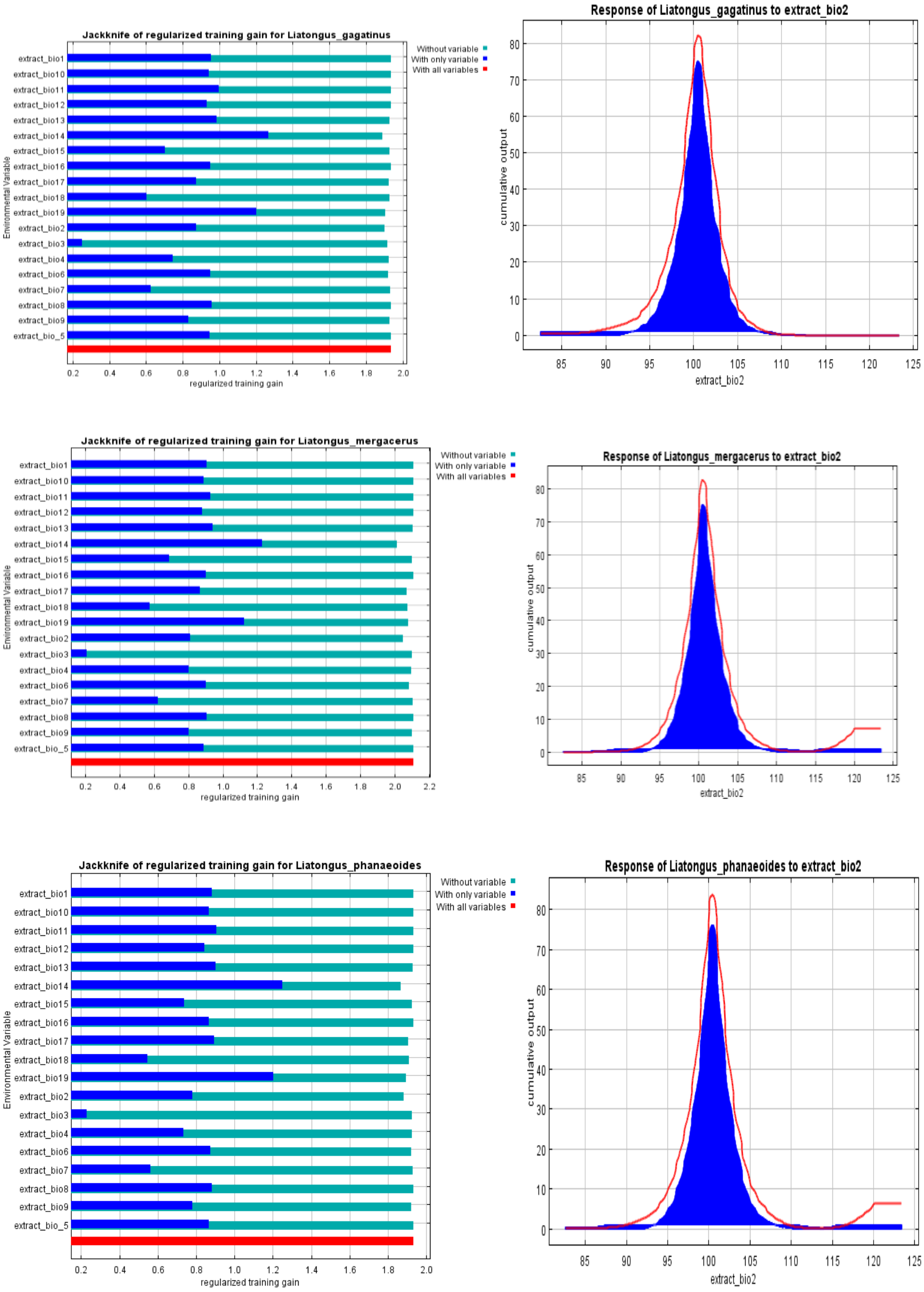
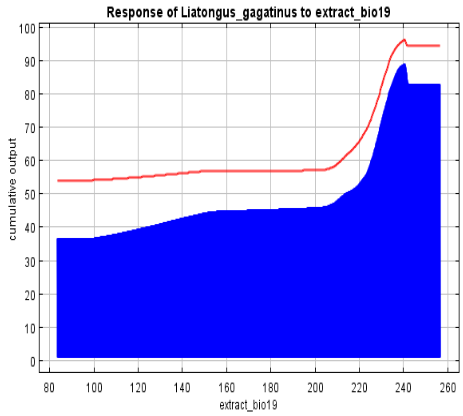
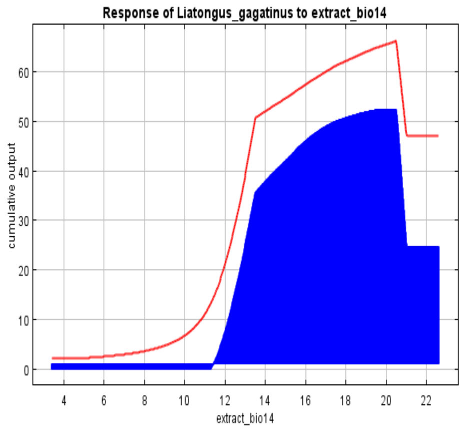
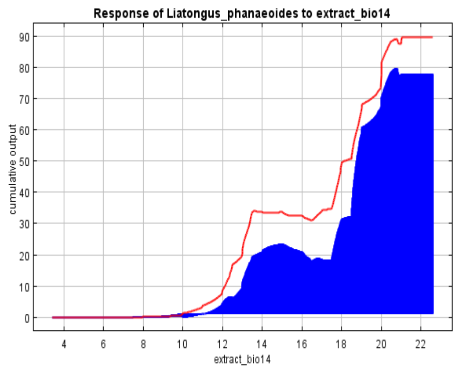


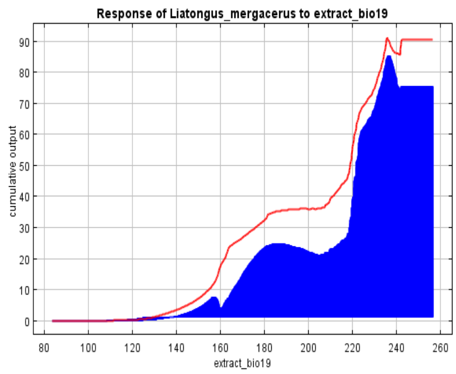
Plate No. 24

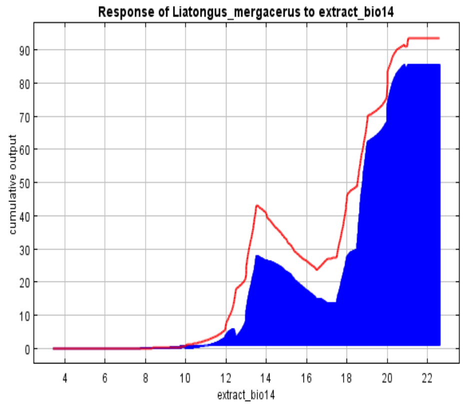
Cumulative output for Precipitation of Driest month (Bio14) & Precipitation of Coldest Quarter (Bio19) of *Liatongus gagatinus*, *L. mergacerus* and *L. phanaeoides* in KSL India.











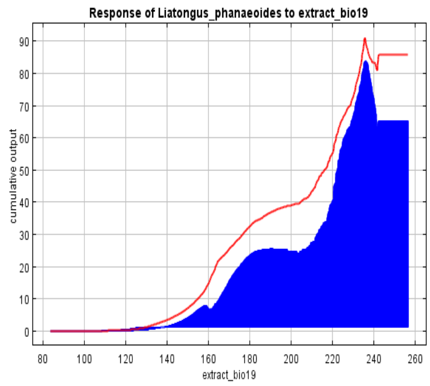
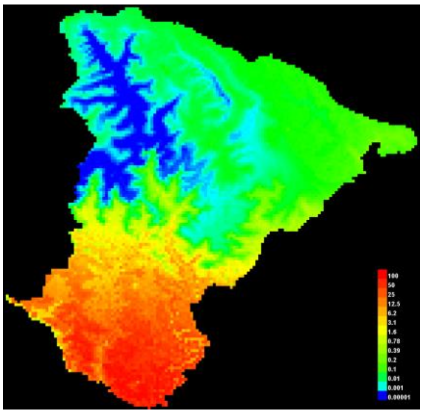
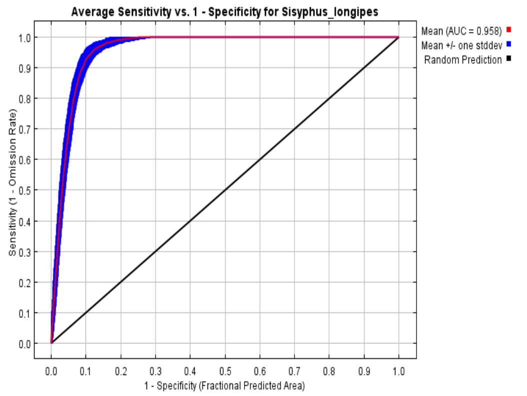
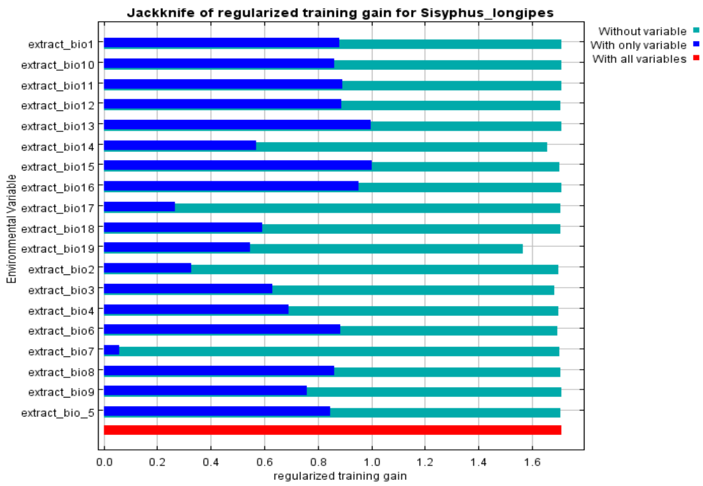


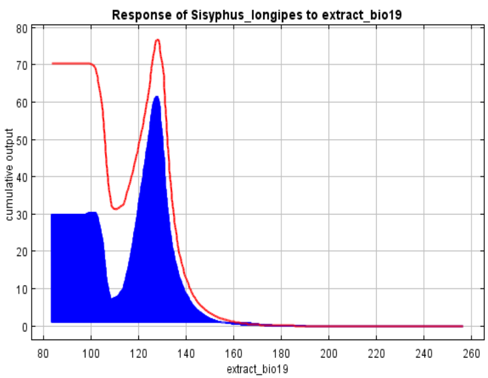
Plate No. 25

MaxEnt output, Jack-knifed environmental variables; cumulative output for Precipitation of Coldest Quarter (Bio19) & Precipitation of Seasonality (Bio15) of *Sisyphus longipes* in KSL India









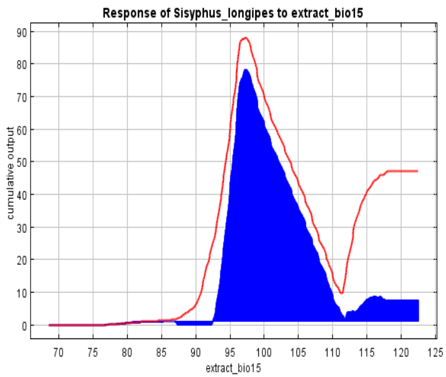
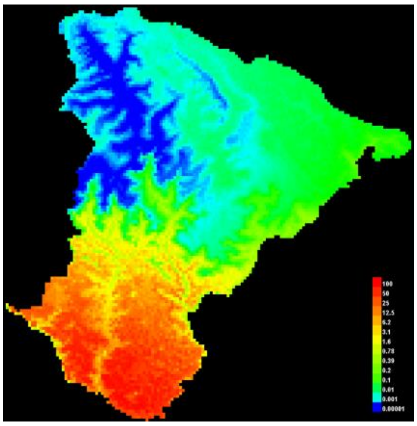
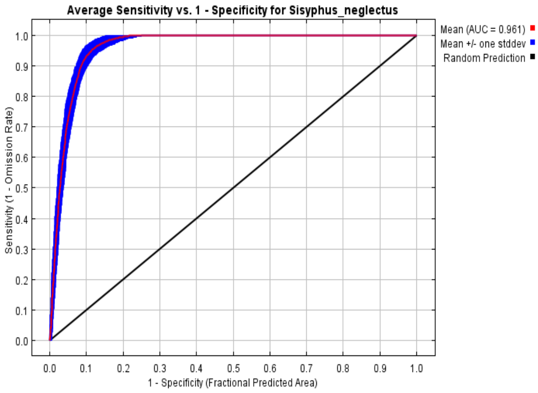
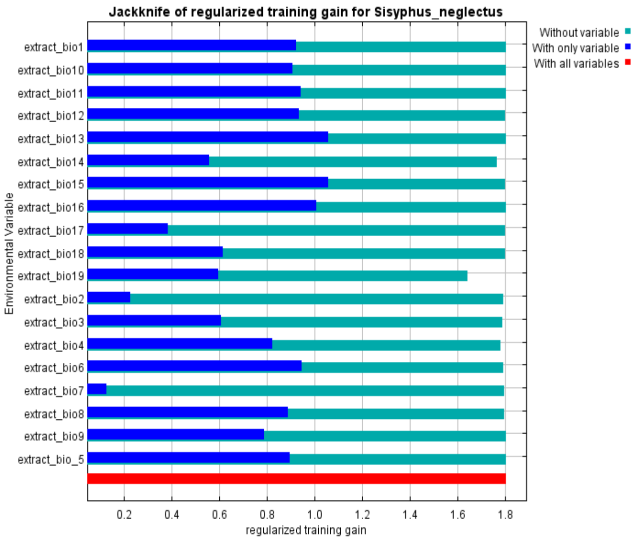


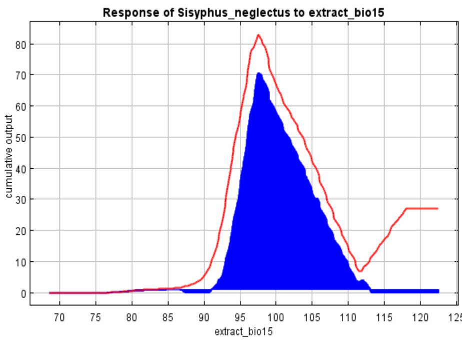
Plate No. 26

MaxEnt output, Jack-knifed environmental variables; cumulative output for Precipitation of Seasonality (Bio15) & Precipitation of Coldest Quarter (Bio19) of *Sisyphus neglectus* in KSL India.









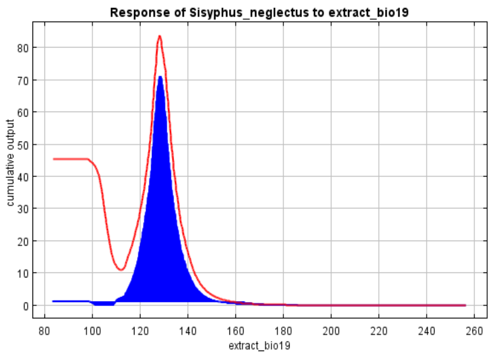
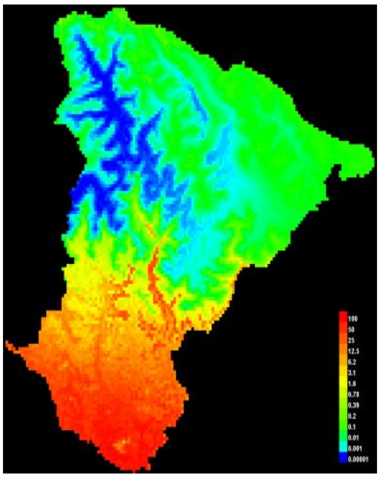
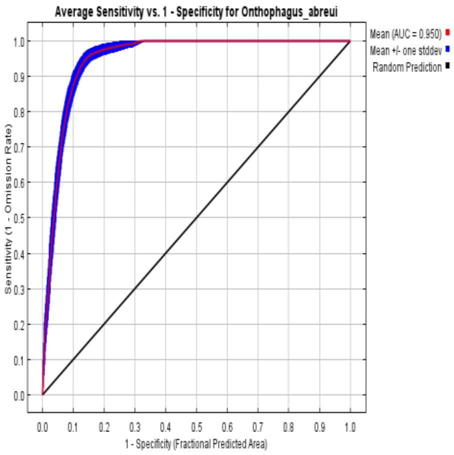
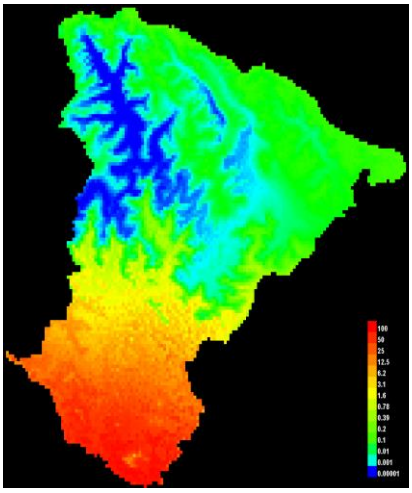


Plate No. 27

MaxEnt output of *Onthophagus abreui* and *O. gagates* in KSL India.







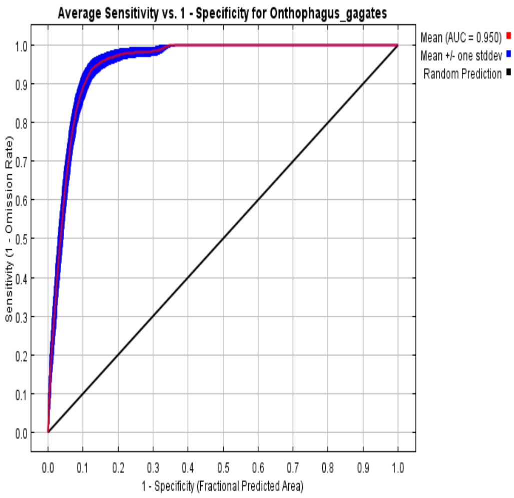


Plate No. 28

Jack-knifed environmental variables; cumulative output for Annual Precipitation (Bio12) of *Onthophagus abreui* and *O. gagates* in KSL India.

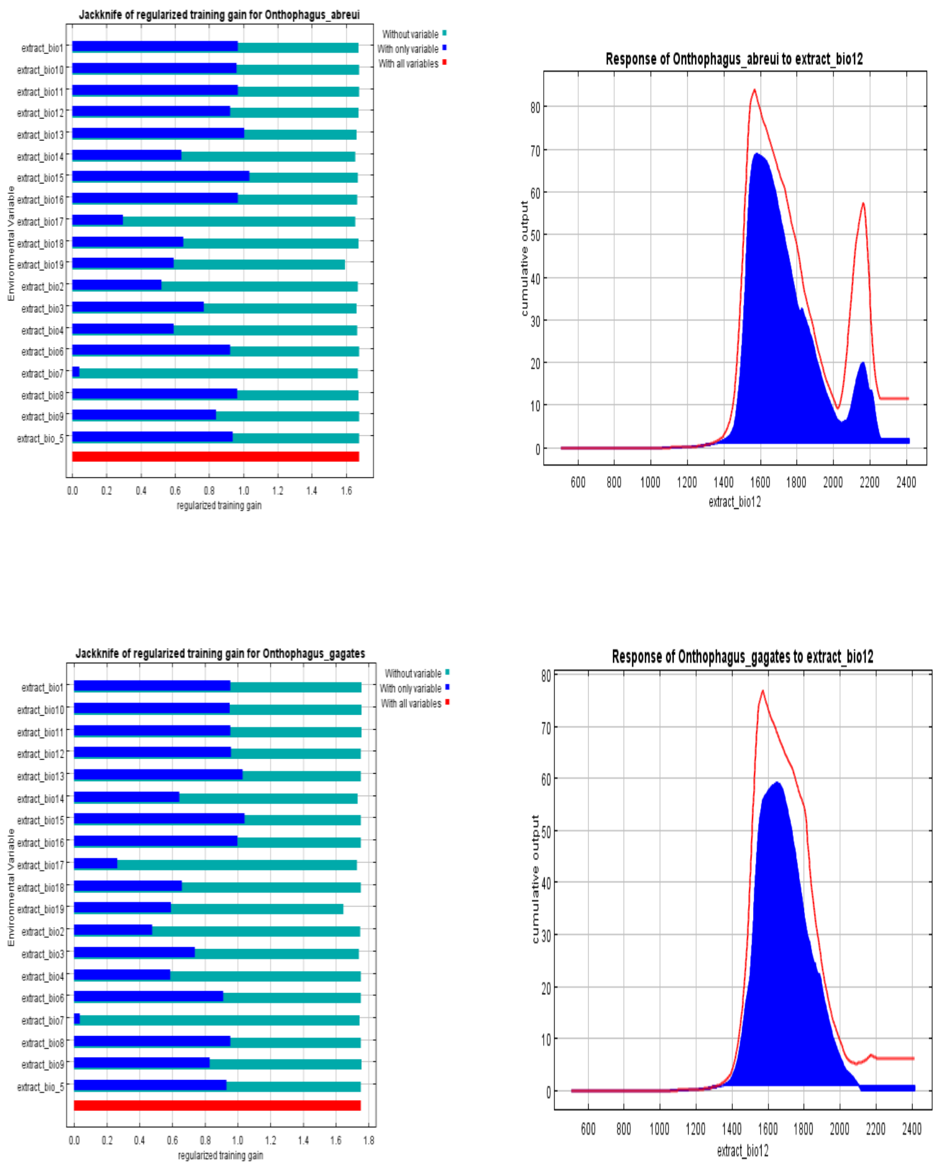


Plate No. 29

Cumulative output for Precipitation Seasonality (Bio15) & Precipitation of Coldest Quarter (Bio19) of *Onthophagus abreui* and *O. gagates* in KSL India.

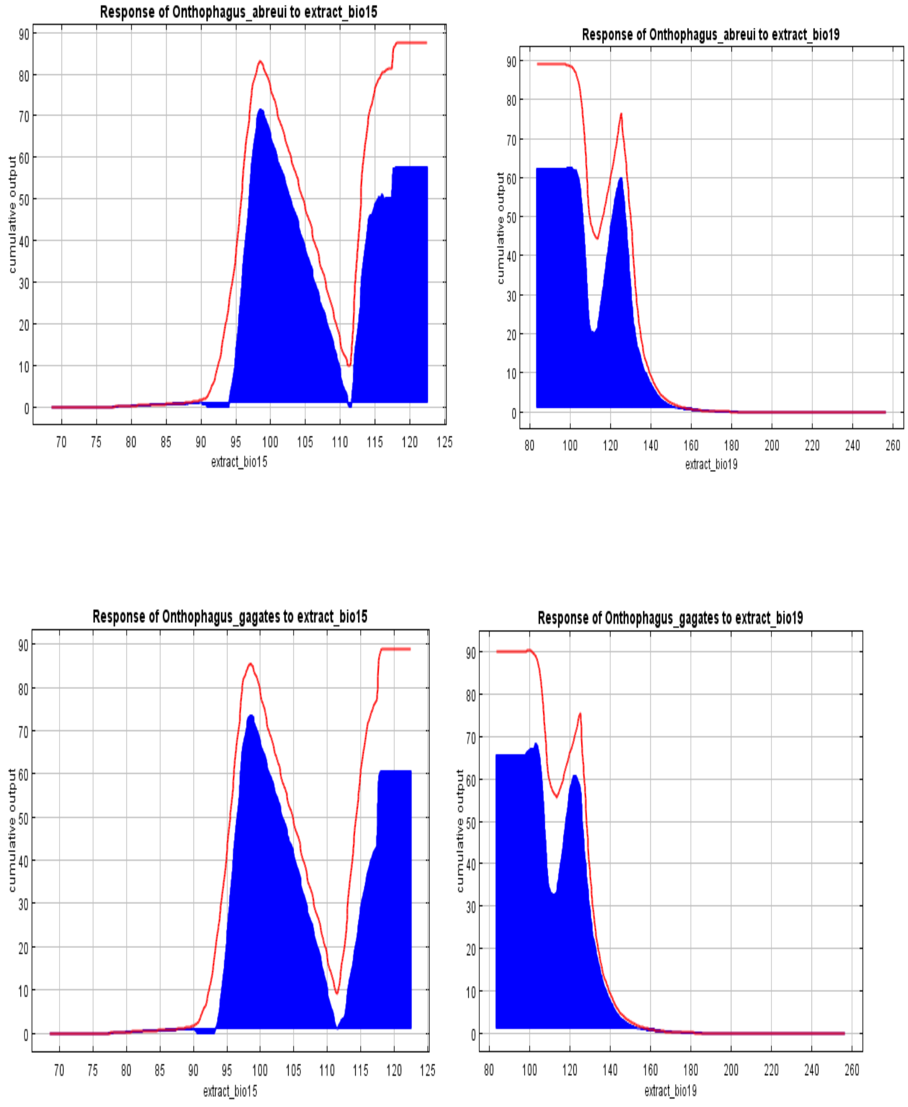
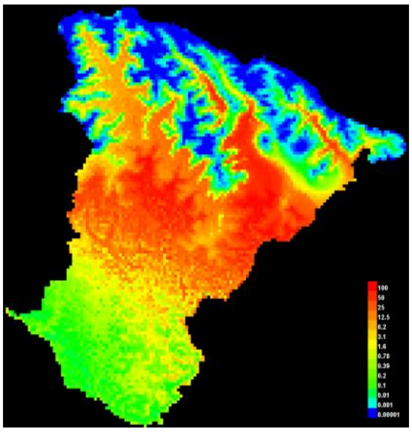
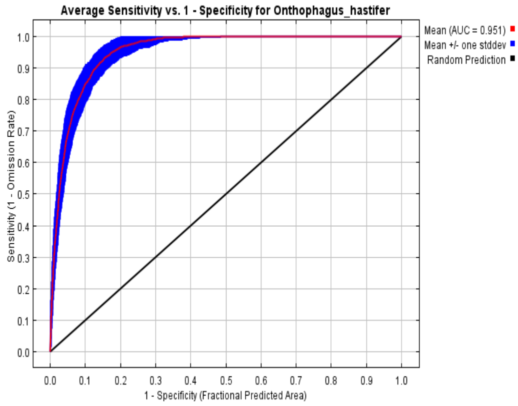
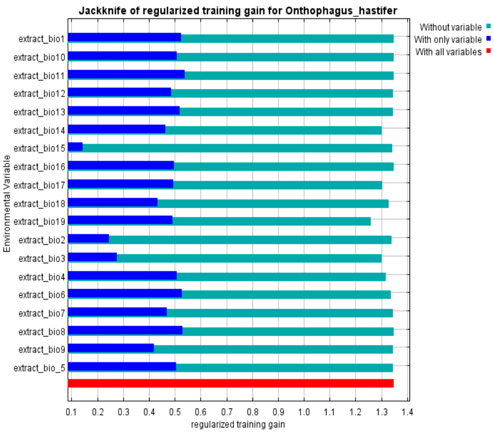


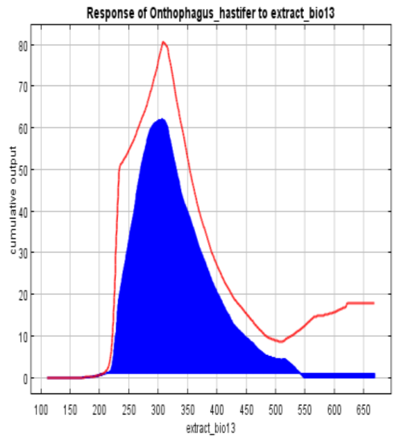
Plate No. 30

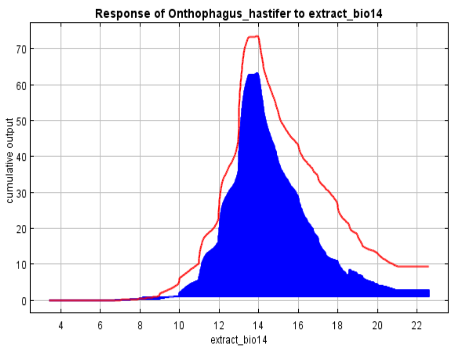
MaxEnt output, Jack-knifed environmental variables; cumulative output for Precipitation of Wettest month (Bio13), Precipitation of Driest month (Bio14) & Precipitation of Coldest Quarter (Bio19) of *Onthophagus hastifer* in KSL India.











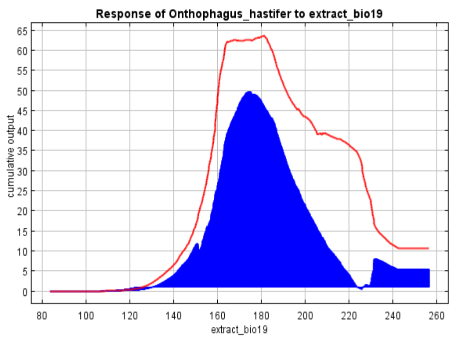


Plate No. 31

MaxEnt output of *Onthophagus dama* and *O. ramosellus* in KSL India.

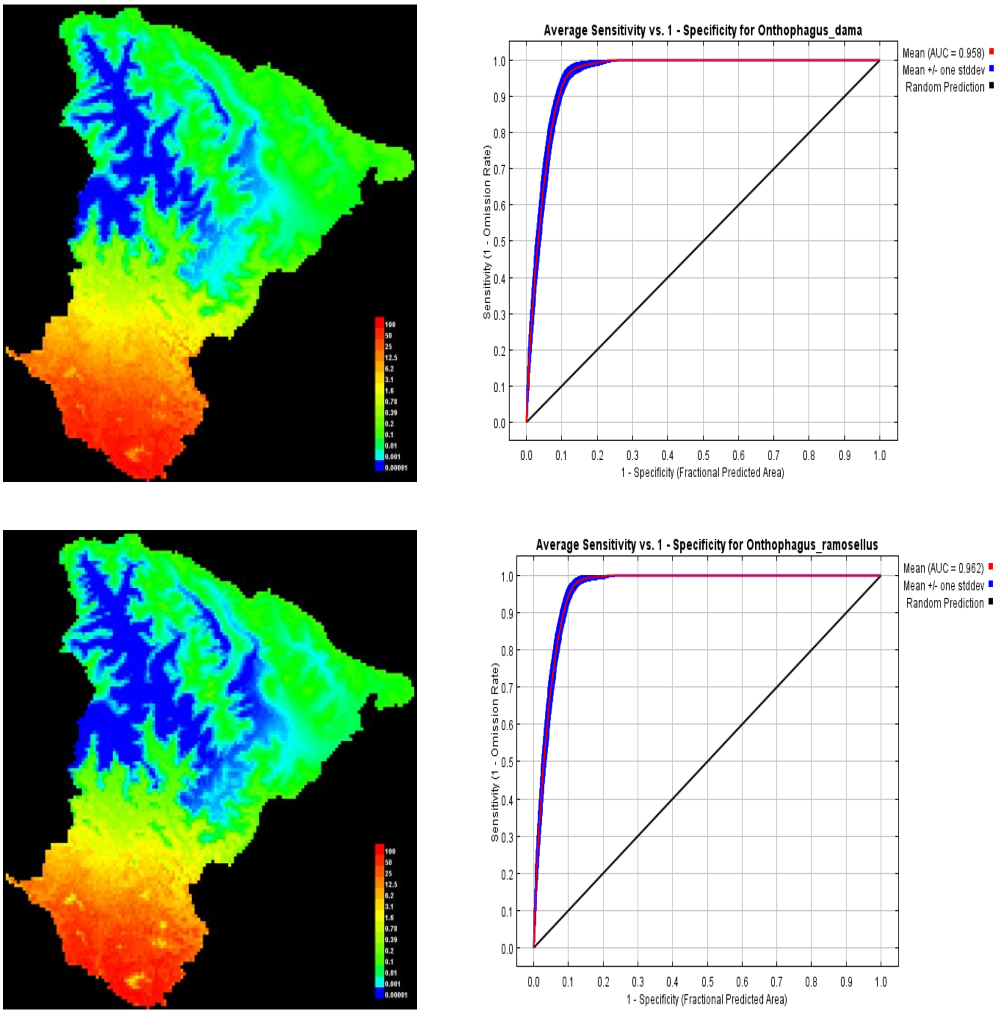
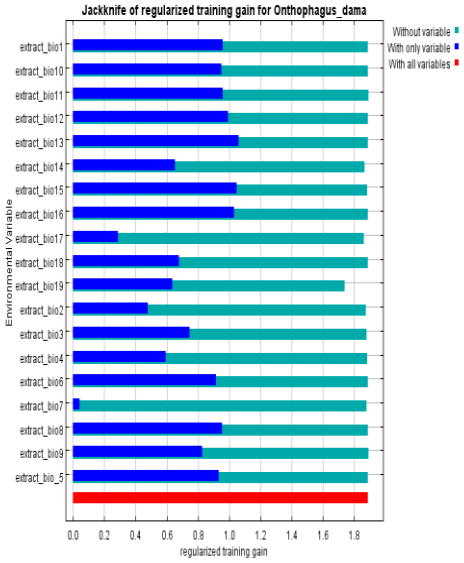
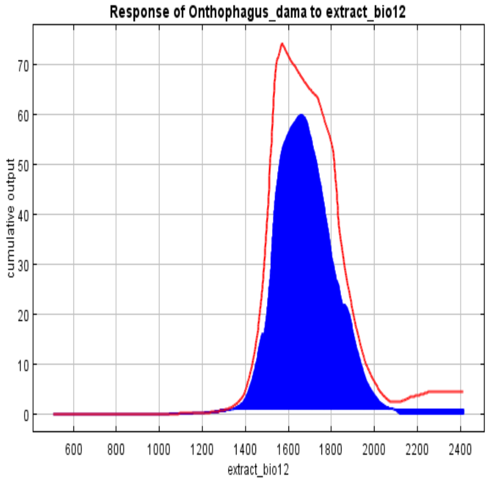
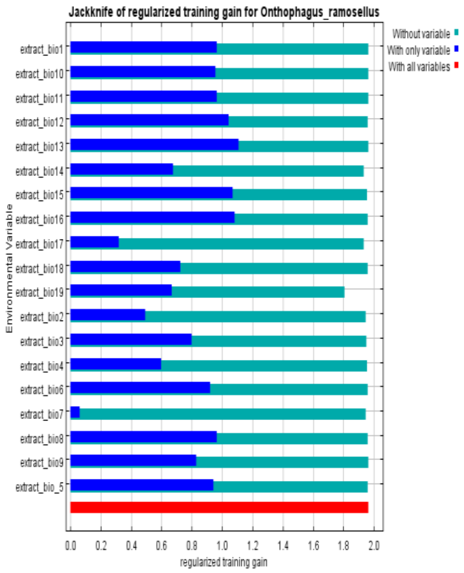


Plate No. 32

Jackknifed environmental variables; cumulative output for Annual Precipitation (Bio12) of *Onthophagus dama* and *O. ramosellus* in KSL India.







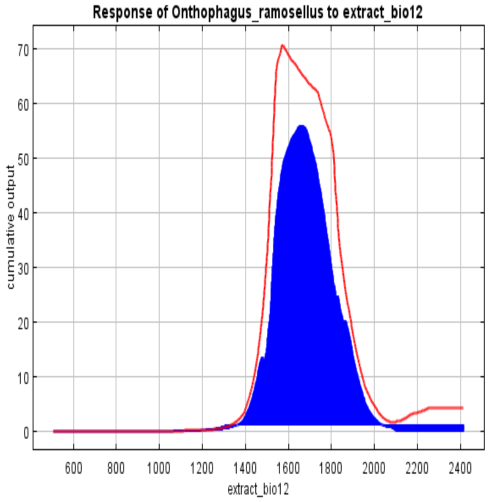
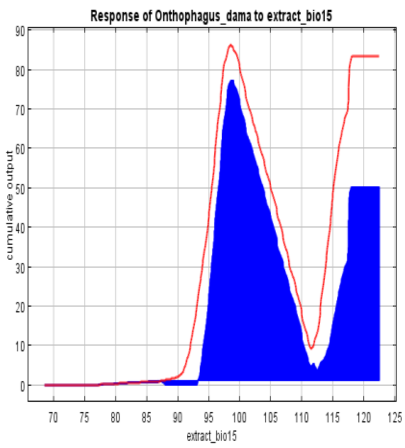
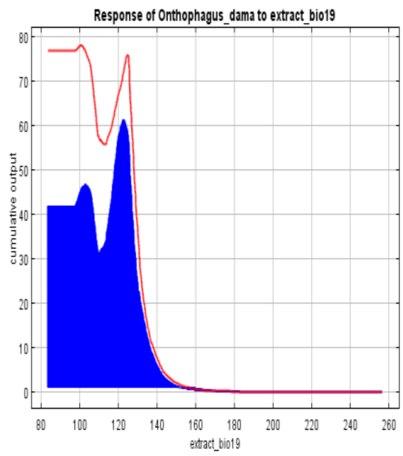
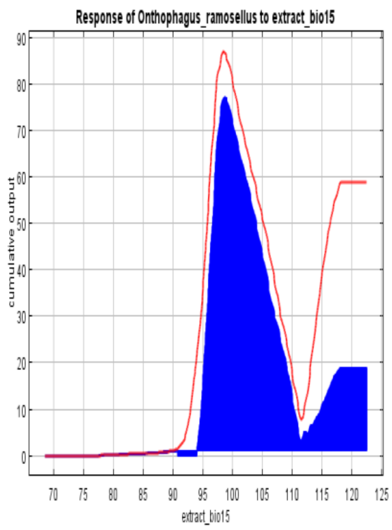


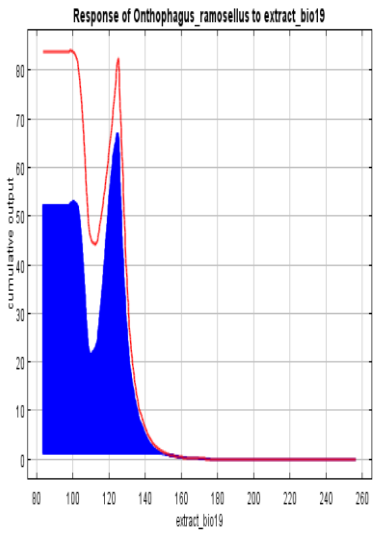
Plate No. 33

Cumulative output for Precipitation Seasonality (Bio15) & Precipitation of Coldest Quarter (Bio19) of *Onthophagus dama* and *O. ramosellus* in KSL India.









7.4 Discussion

In the present work, the high AUC values of Maxent modelling suggested that suitable and unsuitable areas for the predicted distributions were well discriminated and model performances were accurate (Philips et al. 2006; Pearce & Ferrier 2000; Manel et al. 2001). Similar work on the Australian aquatic beetle genus *Antiporus* showed that the Maxent algorithm was appropriate for ecological modelling of south-eastern and south-western population of *A. femoralis* (Hawlitschek et al. 2011). The reasons behind underrepresented areas (Plate No. 15-33) in the models can be (a) climatic conditions in the region may be unsuitable for dung beetles as there is 'no gain' for precipitation of coldest quarter and (b) lack of extensive sampling in that particular region (Sánchez-Fernández et al. 2011). The Jack-knifing of environmental variables showed that variables of temperature and precipitation *viz*., precipitation seasonality, annual precipitation, precipitation of wettest month, precipitation of driest month and precipitation of coldest quarter were common between species. Similar climatic factors such as the precipitation of warmest quarter and precipitation seasonality were found to be significant for *A. occidentalis* while annual mran temperature and annual precipitation were important for *A. femoralis* (Hawlitschek et al. 2011). The temperature and precipitation are interacting with environmental factors.

Therefore, selection of the climatic factor showing their seasonality was essential. The most significant bioclimatic factors extracted by PCA in my study were used to avoid overfitting of the model, which can otherwise happen due to use several correlated factors. The precipitation of wettest month and that of the wettest quarter showed similar trends as annual precipitation and precipitation seasonality; can occur in the wettest month of the monsoon. Precipitation seasonality affected *Caccobius*, *Catharsius, Oniticellus, Tinocellus*, *Onitis*, *Sisyphus*, *Onthophagus* but not over the *Liatongus*. The reason behind such a trend can be that all the representative species had broad distributional data encompassing different climatic regions of India. Therefore, more locality data will yield more information about the environmental needs of the variant. However, now I have preliminary data of probable presence based on which I can search for the variant specimens for further studies.

Several international agencies are working for the establishment of impact of climate change on ecosystems and the people. The main aim of Intergovernmental Panel on Climate Change (IPCC) is to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts. UNFCC, IPCC, MEA and CBD have a common target of biodiversity conservation, sustainable development and updated scientific knowledge for better understanding of climate change. We lack crucial historical data on species distribution. Geographic information system (GIS) combining with all available biological information is a significant tool to fill this gap. This information can help in understanding the impact of climate change and also to monitor the biodiversity loss at steady rate. Policy makers and conservationist can use these insights in order to prioritize the conservation area and efforts, management policies and decisions. Himalaya is one of the most vulnerable ecosystems to climate change. The impacts of extreme events are amplified in the fragile ecosystems of the Himalaya. There is critical need of conservation interventions for the documentation of biodiversity and digitization of all the described taxonomic groups in the Himalaya. This study describe the current and possible distribution of the dung beetles in the landscape.

Adam, W., Janssens, A. & Van Meel, L. (1961). Exploration Parc National de l'Upemba Mission G.F. de Witte. 47pp.

Alvarado, F., Escobar, F. & Montero-Muñoz, J. (2014). Diversity and biogeographical makeup of the dung beetle communities inhabiting two mountains in the Mexican Transition Zone. *Organisms Diversity & Evolution*, *14*(1), 105-114.

Andresen, E. (2003). Effect of forest fragmentation on dung beetle communities and functional consequences for plant regeneration. *Ecography*, *26*(1), 87-97.

Andresen, E. (2005). Effects of Season and Vegetation Type on Community Organization of Dung Beetles in a Tropical Dry Forest 1. *Biotropica: The Journal of Biology and Conservation*, *37*(2), 291-300.

Arnett, R. H. (1968). The beetles of the United States (a manual for identification). The American Entomological Institute. *Ann Arbor, Michigan*, *11*, 12.

Aguirre-Gutiérrez, J., Carvalheiro, L.G., Polce, C., van Loon, E.E., Raes, N., Reemer, M. & Biesmijer (2013). Fit-for-Purpose: Species Distribution Model Performance Depends on Evaluation Criteria– Dutch Hoverflies as a Case Study. PLoS One *8*(*5*): e63708. https://doi.org/10.1371/journal.pone.0063708

Arrow, G.J. (1927). Notes on the Coleopterous genus Sisyphus. *Annual Magazine of Natural History*,*9*(19), 456-465.

Arrow, G.J. (1931). The Fauna of British India including Ceylon and Burma. Col. Lamell. III (Coprinae). *Taylor & Francis London*, XII: 428pp.

Arya, K.L. (1991). Working plan for the Pithoragarh forest division for the period 1991-1992 to 2000-2001, Working Plan Circle

Arya, M. K. & Joshi, P. C. (2014). Studies on the Beetles (Insecta: Coleoptera) In The Nanda Devi Biosphere Reserve, Western Himalayas, Uttarakhand, India. *New York Science Journal*, *7*(1), 25-32.

Audino, L. D., Louzada, J. & Comita, L. (2014). Dung beetles as indicators of tropical forest restoration success: Is it possible to recover species and functional diversity?. *Biological Conservation*, *169*, 248-257.

Balthasar, V. (1963a). Monographie der Scarabaeidae und Aphodiidae der Palaearktischen und Orientalischen region. Prague, Verl. Tschechosl. Akad. Wissensch, I, 391 pp., 137 figs., 24 pls.

Balthasar, V. (1963b). Monographie der Scarabaeidae und Aphodiidae der Palaearktischen und Orientalischen region. Prague, Verl. Tschechosl. Akad. Wissensch, II, 627 pp., 226 figs., 16 pls.

Barbero, E., Palestrini, C. & Rolando, A. (1999). Dung beetle conservation: effects of habitat and resource selection (Coleoptera: Scarabaeoidea). *Journal of Insect Conservation*, *3*(2), 75-84.

Barnes, A. D., Emberson, R. M., Chapman, H. M., Krell, F. T. & Didham, R. K. (2014). Matrix habitat restoration alters dung beetle species responses across tropical forest edges. *Biological Conservation*, *170*, 28-37.

Barragán, F., Moreno, C. E., Escobar, F., Bueno-Villegas, J. & Halffter, G. (2014). The impact of grazing on dung beetle diversity depends on both biogeographical and ecological context. *Journal of Biogeography*, *41*(10), 1991-2002.

Batista, M. C., Lopes, G. D. S., Marques, L. J. P. & Teodoro, A. V. (2016). The dung beetle assemblage (Coleoptera: Scarabaeinae) is differently affected by land use and seasonality in northeastern Brazil. *Entomotropica*, *31*(13):95-104.

Biswas, S. (1978a). Studies on the scarab beetles (Coleoptera: Scarabaeidae) of North Eastern India: A new species and notes on other Indian species of subgenus Strandius, genus Onthophagus. *Journal of Bombay Natural History Society*, *75* (3): 911-913.

Biswas, S. (1978b). Studies on the Scarab beetles (Coleoptera: Scarabaeidae) of North- East India, Part II: Three new species and two new record from India. *Journal of Bombay Natural History Society*, *76*: 339-344.

Biswas, S. & S.K. Chatterjee (1985). Insecta: Coleoptera: Scarabaeidae: Coprinae. *Records of the Zoological Survey of India*, *82*(1-4): 147-177.

Biswas, S. & Chatterjee, S. K. (1986). Scarabaeidae (Coleoptera) of Silent Valley, Kerala, India, with description of three new species. Silent Valley special issue. *Records of the Zoological Survey of India*, *82*(1-4), 79-96.

Biswas, S. and S.K. Chatterjee (1991). Insecta: Coleoptera: Scarabaeidae. *In: Zoological Survey of India, State Fauna Series 1: Fauna of Orissa*, *3*, 243-262.

Biswas, S. & A.K. Ghosh (2000). Coleoptera: Scarabaeidae: Scarabaeinae. *In: Zoological Survey of India, State Fauna Series, 4: Fauna of Meghalaya*, 5: 513- 623.

Biswas, S. & S.V. Mulay (2001). Insecta: Scarabid (Coleoptera). *In: Zoological Survey of India, Fauna of Conservation Area Series 11: Fauna of Nilgiri Biosphere Reserve*: 129-142.

Botes, A., McGeoch, M. A. & Van Rensburg, B. J. (2006). Elephant-and human-induced changes to dung beetle (Coleoptera: Scarabaeidae) assemblages in the Maputaland Centre of Endemism. *Biological Conservation*, *130*(4), 573-583.

Buse, J., Šlachta, M., Sladecek, F. X., Pung, M., Wagner, T. & Entling, M. H. (2015). Relative importance of pasture size and grazing continuity for the long-term conservation of European dung beetles. *Biological Conservation*, *187*, 112-119.

Cabrero-Sañudo, F. J. & Lobo, J. M. (2009). Biogeography of Aphodiinae dung beetles based on the regional composition and distribution patterns of genera. *Journal of Biogeography*, *36*(8), 1474-1492.

Cagle, R. F. (1955). The American Biology Teacher, Report of the Southeastern Conference on Biology Teaching. *17*(1), 17-19.

Carpaneto, G. M., Mazziotta, A. & Ieradi, M. (2010). Use of habitat resources by scarab dung beetles in an African savanna. *Environmental entomology*, *39*(6), 1756-1764.

Carpaneto, G. M., Mazziotta, A. & Piattella, E. (2005). Changes in food resources and conservation of scarab beetles: from sheep to dog dung in a green urban area of Rome (Coleoptera, Scarabaeoidea). *Biological Conservation*, *123*(4), 547-556.

Carpaneto, G. M., Mazziotta, A., Pittino, R. & Luiselli, L. (2011). Exploring co-extinction correlates: the effects of habitat, biogeography and anthropogenic factors on ground squirrels–dung beetles associations. *Biodiversity and Conservation*, *20*(13), 3059-3076.

Champion, H.G. & Seth, S.K. (1968). A revised survey of forest types of India. Manager of Publications, Government of India, New Delhi.

Chandra, K. (2000). Inventory of scarabaeid beetles (Coleoptera) from Madhya Pradesh, India. *Zoo's Print Journal*, *15*(11), 359-362.

Chandra, K. (2005). Insect: Coleoptera: Scarabaeidae. *Zoological Survey of Indian Fauna of Western Himalaya (Part 2).* 141-155pp.

Chandra, K. & Ahirwar, S. C. (2005). Scarabaeid beetles of Bandhavgarh National Park, Madhya Pradesh. *Zoos' Print Journal*, *20*(8), 1961-1964.

Chandra, K. & Ahirwar, S.C. (2007). Insecta: Coleoptera: Scarabaeidae. *In: Zoological Survey of India, Fauna of Madhya Pradesh (including Chhattisgarh), State Fauna Series*, *15* (1), 273-300.

Chandra, K. (2009a). Fauna of Pachmarhi Biosphere Reserve. *Conservation Area Series*, *39*, 1-380.

Chandra, K. (2009b). Insecta: Coleoptera, Fauna of Pachmarhi Biosphere Reserve, Conservation Area Series. *39*,259-299.

Chandra, K. (2009b). Insecta: Coleoptera: Scarabaeidae. *In: Zoological Survey of India, Fauna of Bandhavgarh Tiger Reserve, Conservation Area Series*, *40*, 81-88.

Chandra, K. (2009c). Insecta: Coleoptera: Scarabaeidae. *In: Zoological Survey of India, Fauna of Tamil Nadu, State Fauna Series*, *1*, 79-89.

Chandra, K. & Singh, S. P. (2010). Scarabaeid beetles (Coleoptera) of Achanakmar Wildlife Sanctuary, Chhattisgarh. *National Journal of Life Sciences*, *7*(1), 71-74.

Chandra, K. & Gupta, D. (2011). Study of Scarabaeid Beetles (Coleoptera) of Veerangana Durgavati Wildlife Sanctuary, Damoh, Madhya Pradesh, India. *Deccan Current Science*, *5*, 272-278.

Chandra, K. & Gupta, D. (2011b). Two new records of genus Onthophagus Latreille, 1802 (Coleoptera: Scarabaeidae) from Madhya Pradesh, India. *Uttar Pradesh Journal of Zoology*, *31*(2), 253-255.

Chandra, K. & Gupta, D. (2011c). New record of two species of Caccobius from Madhya Pradesh (Coleoptera: Scarabaeidae). *Bionotes*, *13*(3), 117.

Chandra, K. & Gupta, D. (2012a). Diversity and Relative Abundance of Pleurostict Scarabaeidae (Coleoptera) in Achanakmar-Amarkantak Biosphere Reserve, Central India. *World Journal of Zoology*, *7*(2), 147-154.

Chandra, K. & Gupta, D. (2012b). New distributional record of five species of Onthophagus (Coleoptera: Scarabaeidae: Scarabaeinae) from Central India. *Scholarly Journal of Agricultural Science*, *2*(1), 8-12.

Chandra, K. & Gupta, D. (2012c). First report on five species of genus Onthophagus Latreille, 1802 (Coleoptera, Scarabaeidae) from Madhya Pradesh, India, and their description of external male genitalia. *Biodiversity Journal, 3*(2), 99-106.

Chandra, K. Gupta, D., Uniyal, V. P., Bharadwaj, M. & Sanyal, A. K. (2012). Studies on scarabaeid beetles (Coleoptera) of Govind wildlife sanctuary, Garhwal, Uttarakhand, India. In *Biological Forum-An International Journal*, *4* (1), 48-54pp.

Chatterjee S.K. & S. Biswas (2000). Coleoptera: Scarabaeidae: Scarabaeinae. *In: Zoological Survey of India, State Fauna Series, 7: Fauna of Tripura, 3*, 87-98.

Chatterjee S.K. & S. Biswas (2003). Coleoptera: Scarabaeidae: Scarabaeinae. *In: Zoological Survey of India, State Fauna Series, 9: Fauna of Sikkim, 3*, 57-65.

Chauhan, M. & Uniyal, V. P. (2017). Dung Beetles (Scarabaeidae): An Efficient Model for Long Term Ecological Monitoring. *Indian Forester*, *143*(10), 1088-1090.

Chefaoui, R. M., Hortal, J. & Lobo, J. M. (2005). Potential distribution modelling, niche characterization and conservation status assessment using GIS tools: a case study of Iberian Copris species. *Biological Conservation*, *122*(2), 327-338.

Chown, S. L., Scholtz, C. H., Klok, C. J., Joubert, F. J. & Coles, K. S. (1995). Ecophysiology, range contraction and survival of a geographically restricted African dung beetle (Coleoptera: Scarabaeidae). *Functional Ecology*, 30-39.

Culot, L., Bovy, E., Vaz-de-Mello, F. Z., Guevara, R. & Galetti, M. (2013). Selective defaunation affects dung beetle communities in continuous Atlantic rainforest. *Biological Conservation*, *163*, 79-89.

Culot, L., Huynen, M. C. & Heymann, E. W. (2018). Primates and dung beetles: two dispersers are better than one in secondary forest. *International Journal of Primatology*, *39*(3), 397-414.

Culot, L., Mann, D. J., Muñoz Lazo, F. J., Huynen, M. C. & Heymann, E. W. (2011). Tamarins and dung beetles: an efficient diplochorous dispersal system in the Peruvian Amazonia. *Biotropica*, *43*(1), 84-92.

Damborsky, M. P., Bohle, M. A., Polesel, M. I., Porcel, E. A. & Fontana, J. L. (2015). Spatial and temporal variation of dung beetle assemblages in a fragmented landscape at eastern humid Chaco. *Neotropical entomology*, *44*(1), 30-39.

Davis, A. L. (1996). Seasonal dung beetle activity and dung dispersal in selected South African habitats: Implications for pasture improvement in Australia. *Agriculture Ecosystems & Environment, 58*, 157-169.

Davis, A. (1997). Climatic and biogeographical associations of southern African dung beetles (Coleoptera: Scarabaeidae s. str.). *African Journal of ecology*, *35*(1), 10-38.

Davis, A. J. & Sutton, S. L. (1997). A dung beetle that feeds on fig: implications for the measurement of species rarity. *Journal of Tropical Ecology*, *13*(5), 759-766.

Davis, A. J. (2000). Does reduced-impact logging help preserve biodiversity in tropical rainforests? A case study from Borneo using dung beetles (Coleoptera: Scarabaeoidea) as indicators. *Environmental Entomology*, *29*(3), 467-475.

Davis, A. J. Holloway, J. D., Huijbregts, H., Krikken, J., Kirk-Spriggs, A. H. & Sutton, S. L. (2001). Dung beetles as indicators of change in the forests of northern Borneo. *Journal of Applied Ecology*, *38*(3), 593-616.

Davis, A. J. Huijbregts, H. & Krikken, J. (2000). The role of local and regional processes in shaping dung beetle communities in tropical forest plantations in Borneo. *Global Ecology and Biogeography*, *9*(4), 281-292.

Davis, A. L. (1994). Habitat fragmentation in southern Africa and distributional response patterns in five specialist or generalist dung beetle families (Coleoptera). *African Journal of Ecology*, *32*(3), 192-207.

Davis, A. L. Scholtz, C. H. & Chown, S. L. (1999). Species turnover, community boundaries and biogeographical composition of dung beetle assemblages across an altitudinal gradient in South Africa. *Journal of Biogeography*, *26*(5), 1039-1055.

Davis, A. L. & Scholtz, C. H. (2001). Historical vs. ecological factors influencing global patterns of scarabaeine dung beetle diversity. *Diversity and Distributions*, *7*(4), 161-174.

Davis, A. L., Scholtz, C. H. & Philips, T. K. (2002). Historical biogeography of scarabaeine dung beetles. *Journal of Biogeography*, *29*(9), 1217-1256.

Davis, A. L., Scholtz, C. H. & Deschodt, C. (2008). Multi-scale determinants of dung beetle assemblage structure across abiotic gradients of the Kalahari–Nama Karoo ecotone, South Africa. *Journal of Biogeography*, *35*(8), 1465-1480.

Didham, R. K. (1997). An overview of invertebrate responses to forest fragmentation. *Forests and insects*, 303-320.

Didham, R. K. (1997). The influence of edge effects and forest fragmentation on leaf litter invertebrates in central Amazonia. *Tropical forest remnants: ecology, management, and conservation of fragmented communities. University of Chicago Press, Chicago*, 55-70.

Didham, R. K., Ghazoul, J., Stork, N. E. & Davis, A. J. (1996). Insects in fragmented forests: a functional approach. *Trends in Ecology & Evolution*, *11*(6), 255-260.

Didham, R. K., Lawton, J. H., Hammond, P. M. & Eggleton, P. (1998). Trophic structure stability and extinction dynamics of beetles (Coleoptera) in tropical forest fragments. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, *353*(1367), 437-451.

Doll, H. M., Butod, E., Harrison, R. D., Fletcher, C., Kassim, A. R., Ibrahim, S. & Doll, H. M. (2014). Environmental and geographic factors driving dung beetle (Coleoptera: Scarabaeidae: Scarabaeinae) diversity in the dipterocarp forests of Peninsular Malaysia.

Doube, B. M. (1991). Dung beetles of southern Africa. *Dung beetle ecology*, 133-155.

Dufrêne, M. & Legendre, P. (1997). Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecological monographs*, *67*(3), 345-366.

Edwards, F.A., Finan, J., Grahamb, L. K., Larsen, T.H., Wilcove, D.S., Hsu, W.W., Chey, V.K. & Hamer, K. C. (2017). The impact of logging roads on dung beetle assemblages in a tropical rainforest reserve. *Biological Conservation*, *205*, 85–92.

Edwards, P. B. (1991). Seasonal variation in the dung of African grazing mammals, and its consequences for coprophagous insects. *Functional Ecology*, 617-628.

Edwards, P. B. & Aschenborn, H. H. (1987). Patterns of nesting and dung burial in Onitis dung beetles: implications for pasture productivity and fly control. *Journal of Applied Ecology*, 837-851.

Escobar, F., Halffter, G. & Arellano, L. (2007). From forest to pasture: an evaluation of the influence of environment and biogeography on the structure of beetle (Scarabaeinae) assemblages along three altitudinal gradients in the Neotropical region. *Ecography*, *30*(2), 193-208.

Escobar, F., Halffter, G. & Arellano, L. (2007). From forest to pasture: an evaluation of the influence of environment and biogeography on the structure of beetle (Scarabaeinae) assemblages along three altitudinal gradients in the Neotropical region. *Ecography*, *30*(2), 193-208.

Escobar, S. (2000). Diversity of coprophagous beetles (Scarabaeidae: Scarabaeinae) in a mosaic of habitats in the Nukak Natural Reserve, Guaviare, Colombia. *Acta Zoologica Mexicana*, (79), 103-121.

Estrada, A. & Coates-Estrada, R. (1991). Howler monkeys (Alouatta palliata), dung beetles (Scarabaeidae) and seed dispersal: ecological interactions in the tropical rain forest of Los Tuxtlas, Mexico. *Journal of Tropical Ecology*, *7*(4), 459-474.

Estrada, A., Anzures, D. A. & Coates-Estrada, R. (1999). Tropical rain forest fragmentation, howler monkeys (Alouatta palliata), and dung beetles at Los Tuxtlas, Mexico. *American Journal of Primatology: Official Journal of the American Society of Primatologists*, *48*(4), 253-262.

Estrada, A. & Coates-Estrada, R. (2002). Dung beetles in continuous forest, forest fragments and in an agricultural mosaic habitat island at Los Tuxtlas, Mexico. *Biodiversity & Conservation*, *11*(11), 1903-1918.

Estrada, A., Coates-Estrada, R. & Meritt Jr, D. (1994). Non flying mammals and landscape changes in the tropical rain forest region of Los Tuxtlas, Mexico. *Ecography*, *17*(3), 229-241.

Estrada, A., Coates-Estrada, R., Dadda, A. A. & Cammarano, P. (1998). Dung and carrion beetles in tropical rain forest fragments and agricultural habitats at Los Tuxtlas, Mexico. *Journal of Tropical Ecology*, *14*(5), 577-593.

Estrada, A., Halffter, G., Coates-Estrada, R. & Meritt, D. A. (1993). Dung beetles attracted to mammalian herbivore (Alouatta palliata) and omnivore (Nasua narica) dung in the tropical rain forest of Los Tuxtlas, Mexico. *Journal of Tropical ecology*, *9*(1), 45-54.

Estrada, A., Halffter, G., Coates-Estrada, R. & Meritt, D. A. (1993). Dung beetles attracted to mammalian herbivore (Alouatta palliata) and omnivore (Nasua narica) dung in the tropical rain forest of Los Tuxtlas, Mexico. *Journal of Tropical ecology*, *9*(1), 45-54.

Fahrig, L. (2001). How much habitat is enough?. *Biological conservation*, *100*(1), 65-74.

Feer, F. (1999). Effects of dung beetles (Scarabaeidae) on seeds dispersed by howler monkeys (Alouatta seniculus) in the French Guianan rain forest. *Journal of Tropical Ecology*, *15*(2), 129-142.

Feer, F. & Pincebourde, S. (2005). Diel flight activity and ecological segregation within an assemblage of tropical forest dung and carrion beetles. *Journal of Tropical Ecology*, *21*(1), 21-30.

Filgueiras, B. K., Iannuzzi, L. & Leal, I. R. (2011). Habitat fragmentation alters the structure of dung beetle communities in the Atlantic Forest. *Biological Conservation*, *144*(1), 362-369.

Filgueiras, B. K., Tabarelli, M., Leal, I. R., Vaz-de-Mello, F. Z. & Iannuzzi, L. (2015). Dung beetle persistence in human-modified landscapes: combining indicator species with anthropogenic land use and fragmentation-related effects. *Ecological Indicators*, *55*, 65-73.

Filgueiras, B. K., Tabarelli, M., Leal, I. R., Vaz-d--Mello, F. Z., Peres, C. A. & Iannuzzi, L. (2016). Spatial replacement of dung beetles in edge-affected habitats: biotic homogenization or divergence in fragmented tropical forest landscapes?. *Diversity and Distributions*, *22*(4), 400-409.

Finn, J. A. & Giller, P. S. (2000). Patch size and colonisation patterns: an experimental analysis using north temperate coprophagous dung beetles. *Ecography*, *23*(3), 315-327.

Finn, J. A. & Giller, P. S. (2002). Experimental investigations of colonisation by north temperate dung beetles of different types of domestic herbivore dung. *Applied Soil Ecology*, *20*(1), 1-13.

França, F. M., Frazão, F. S., Korasaki, V., Louzada, J. & Barlow, J. (2017). Identifying thresholds of logging intensity on dung beetle communities to improve the sustainable management of Amazonian tropical forests. *Biological Conservation*, *216*, 115-122.

Gajendra, N. &. Prasad, S. K. (2015) A Review of Coleoptera Diversity of Chhattisgarh: Updated Checklist. *International Journal of Science and Research, 5*(4): 710-714.

Galante, E., Mena, J. & Lumbreras, C. J. (1993). Study of the spatio-temporal distribution in a coprophagous community in a Mediterranean holm-oak ecosystem (Coleoptera: Scarabaeoidea: Scarabaeidae: Geitrupidae). *Elytron*, *7*, 87-97.

García-Tejero, S., Taboada, Á., Tárrega, R. & Salgado, J. M. (2013). Land use changes and ground dwelling beetle conservation in extensive grazing dehesa systems of north-west Spain. *Biological conservation*, *161*, 58-66.

Gardner T.A., Barlow J., Araujo I.S., Avila-Pires T.C., Bonaldo A.B., Costa J.E., Esposito M.C., Ferreira L.V., Hawes J., Hernandez M.I., Hoogmoed M.S., Leite R.N., Lo-Man-Hung N.F., Malcolm J.R., Martins M.B., Mestre L.A., Miranda-Santos R., Overal W.L., Parry L., Peters S.L., Ribeiro-Junior M.A., da Silva M.N., da Silva M.C. & Peres C.A. (2008). The cost-effectiveness of biodiversity surveys in tropical forests. *Ecological Letters, 11*:139-150

Gardner, T. A., Hernández, M. I., Barlow, J. & Peres, C. A. (2008). Understanding the biodiversity consequences of habitat change: the value of secondary and plantation forests for neotropical dung beetles. *Journal of applied ecology*, *45*(3), 883-893.

Gascon, C., Lovejoy, T. E., Bierregaard Jr, R. O., Malcolm, J. R., Stouffer, P. C., Vasconcelos, H. L. & Borges, S. (1999). Matrix habitat and species richness in tropical forest remnants. *Biological conservation*, *91*(2-3), 223-229.

Gaston, K. J. & Chown, S. L. (1999). Elevation and climatic tolerance: a test using dung beetles. *Oikos*, 584-590.

Gill, B. D. (1991). Dung beetles in tropical American forests. *Dung beetle ecology*.

Giller, P. S. & Doube, B. M. (1994). Spatial and temporal co-occurrence of competitors in Southern African dung beetle communities. *Journal of Animal Ecology*, 629-643.

Gittings, T. (1994). The community ecology of Aphodius dung beetles. *Unpublished PhD thesis, National University of Ireland*.

Gittings, T. & Giller, P. S. (1997). Life history traits and resource utilisation in an assemblage of north temperate Aphodius dung beetles (Coleoptera: Scarabaeidae). *Ecography*, *20*(1), 55-66.

Gittings, T. & Giller, P. S. (1998). Resource quality and the colonisation and succession of coprophagous dung beetles. *Ecography, 21*(6), 581-592.

Griffiths, H. M., Bardgett, R. D., Louzada, J. & Barlow, J. (2016). The value of trophic interactions for ecosystem function: dung beetle communities influence seed burial and seedling recruitment in tropical forests. *Proceedings of the Royal Society B: Biological Sciences*, *283*(1844), 16-34.

Halffter, G., Favila, M. E. & Halffter, V. (1992). A comparative study of the structure of the scarab guild in Mexican tropical rain forests and derived ecosystems. *Folia Entomológica Mexicana*, *84*(13), 155.

Halffter, G. (1993). The Scarabaeinae (Insecta: Coleoptera) an animal group for analyzing, inventorying and monitoring biodiversity in tropical rainforest and modified landscapes. *Biology International 27*, 15-21.

Halffter, G. & Arellano, L. (2002). Response of Dung Beetle Diversity to Human–induced Changes in a Tropical Landscape. *Biotropica*, *34*(1), 144-154.

Hawlitshek, O., Porch, N., Hendrich, L. & Balke, M. (2011). Ecological niche modelling and nDNA sequencing support a new, morpholocally cryptic beetle species unveiled by DNA barcoding. *Plos One*, *6e*, 16662.

Hamel-Leigue, A. C., Herzog, S. K., Larsen, T. H., Mann, D. J., Gill, B. D., Edmonds, W. D. & Spector, S. (2013). Biogeographic patterns and conservation priorities for the dung beetle tribe P hanaeini (C oleoptera: S carabaeidae: S carabaeinae) in Bolivia. *Insect Conservation and Diversity*, *6*(3), 276-289.

Han, Y. G., Kwon, O. & Cho, Y. (2015). A study of bioindicator selection for long-term ecological monitoring. *Journal of Ecology and Environment*, *38*(1), 119-122.

Hanski, I. (1991). The dung insect community. Dung beetle ecology. Princeton University Press, Princeton, New Jersey, 5-21

Hidayat, P., Manuwoto, S., Noerdjito, W. A., Tscharntke, T. & Schulze, C. H. (2010). Diversity and body size of dung beetles attracted to different dung types along a tropical land-use gradient in Sulawesi, Indonesia. *Journal of Tropical Ecology*, *26*(1), 53-65.

Hill, C. J. (1996). Habitat specificity and food preferences of an assemblage of tropical Australian dung beetles. *Journal of Tropical Ecology*, *12*(4), 449-460.

Hosaka, T., Niino, M., Kon, M., Ochi, T., Yamada, T., Fletcher, C. & Okuda, T. (2014a). Effects of logging road networks on the ecological functions of dung beetles in Peninsular Malaysia. *Forest Ecology and Management*, *326*, 18-24.

Hosaka, T., Niino, M., Kon, M., Ochi, T., Yamada, T., Fletcher, C. D. & Okuda, T. (2014b). Impacts of Small-scale Clearings due to Selective logging on Dung Beetle Communities. *Biotropica*, *46*(6), 720-731.

Hughes, R. D., Ferrar, P., Macqueen, A., Durie, P., McKinney, G. T. & Morley, F. H. W. (1975). Introduced dung beetles and Australian pasture ecosystems: papers presented at a symposium during the meeting of the Australia and New Zealand Association for the Advancement of Science at Canberra in January 1975. *Journal of Applied Ecology*, *12*(3), 819-837.

Inward, D. J., Davies, R. G., Pergande, C., Denham, A. J. & Vogler, A. P. (2011). Local and regional ecological morphology of dung beetle assemblages across four biogeographic regions. *Journal of Biogeography*, *38*(9), 1668-1682.

J. Haynes, K. & T. Cronin, J. (2006). Interpatch movement and edge effects: the role of behavioral responses to the landscape matrix. *Oikos*, *113*(1), 43-54.

Jain, R. & Mittal, I. C. (2012). Diversity, faunal composition and conservation assessment of dung beetles (Coleoptera: Scarabaeidae) in two reserve forests of Haryana (India). *Entomologie Faunistique-Faunistic Entomology*. *65*, 69-79

Janssens, A. (1935a). Coprini. *Exploration du Parc National* Albert, Mission G.F. de Witte, 29: 1- 104, 4 pls.

Janssens, A. (1937). Revision des Onitides. *Memoirs du Musee Royal D'Históry. Naturelle de Belgique*, (11): 1-200, 107 figs., 2 pls.

Janssens, A. (1938). Scarabaeini Coleoptera Lamellicornia Fam. Scarabaeidae. Explor, Parc. Natn. Albert. Mission G.F. de Witte, 21: 1-76, 3 pls., 25 figs.

Janssens, A. (1940). Monographie des gymnopleurides. *Memoirs du Musee Royal D'Históry. Naturelle de Belgique*, (2), 1-78.

Janssens, A. (1953). Exploration du Parc National de l'Upemba (Mission GF de Witte). Fascicle 11. Oniticellini (Coleoptera Lamellicornia).

Janzen, D. H., Ataroff, M., Farinas, M., Reyes, S., Rincon, N., Soler, A. & Vera, M. (1976). Changes in the arthropod community along an elevational transect in the Venezuelan Andes. *Biotropica,* 193-203.

Jay-Robert, P., Niogret, J., Errouissi, F., Labarussias, M., Paoletti, É., Luis, M. V. & Lumaret, J. P. (2008). Relative efficiency of extensive grazing vs. wild ungulates management for dung beetle conservation in a heterogeneous landscape from Southern Europe (Scarabaeinae, Aphodiinae, Geotrupinae). *Biological Conservation*, *141*(11), 2879-2887.

Jeannel, R. (1955). LÕedeage. *Initiation aux recherches sur la systematique des coleopteres. Publications Diverses du Museum National d'Histoire Naturelle*, *16*, 155.

Jellinek, S., Parris, K. M. & Driscoll, D. A. (2013). Are only the strong surviving? Little influence of restoration on beetles (Coleoptera) in an agricultural landscape. *Biological conservation*, *162*, 17-23.

Jessop, L. (1985). An identification guide to Eurysternine dung beetles (Coleoptera, Scarabaeidae). *Journal of Natural History*, *19*(6), 1087-1111.

Joshi, P. C., Kothari, K., Badoni, V. P., Arya, M. & Agarwal, A. (2004). Species Composition and Density of Entomofauna Vis a Vis Altitudinal Variations and Disturbances in Nanda Devi Biosphere Reserve, Uttranchal, India. *Asian Journal of Microbiology Biotechnology and Environmental Sciences*, *6*(2), 301-308.

Joshi, P. C., Kumar, K. & Arya, M. (2008). Assessment of insect diversity along an altitudinal gradient in Pinderi forests of Western Himalaya, India. *Journal of Asia-Pacific Entomology*, *11*(1), 5-11.

Jobe, R. T. & Zank, B. 2008. Modelling species distributions for the Great Smoky Mountains National Park using MaxEnt. Electronic File: https://idfg.idaho.gov/species/bibliography/1497986.

Kakkar, N. & Gupta, S. K. (2009). Temporal variations in dung beetle (Coleoptera: Scarabaeidae) assemblages in Kurukshetra, Haryana, India. *Journal of Threatened Taxa*, 481-483.

Klein, B. C. (1989). Effects of forest fragmentation on dung and carrion beetle communities in central Amazonia. *Ecology*, *70*(6), 1715-1725.

Klein, B. C. (1989). Effects of forest fragmentation on dung and carrion beetle communities in central Amazonia. *Ecology*, *70*(6), 1715-1725.

Knopp, T., Rahagalala, P., Miinala, M. & Hanski, I. (2011). Current geographical ranges of Malagasy dung beetles are not delimited by large rivers. *Journal of biogeography*, *38*(6), 1098-1108.

Larsen, T. H., Lopera, A. & Forsyth, A. (2008). Understanding trait-dependent community disassembly: dung beetles, density functions, and forest fragmentation. *Conservation Biology*, *22*(5), 1288-1298.

Larsen, T. H., Lopera, A. & Forsyth, A. (2008). Understanding trait-dependent community disassembly: dung beetles, density functions, and forest fragmentation. *Conservation Biology*, *22*(5), 1288-1298.

Larsen, T. H., Williams, N. M. & Kremen, C. (2005). Extinction order and altered community structure rapidly disrupt ecosystem functioning. *Ecology letters*, *8*(5), 538-547.

Lindenmayer, D. B. & Likens, G. E. (2010). The science and application of ecological monitoring. *Biological conservation*, *143*(6), 1317-1328.

Lobo, J. M. & Davis, A. L. (1999). An intercontinental comparison of dung beetle diversity between two mediterranean-climatic regions: local versus regional and historical influences. *Diversity and Distributions*, *5*(3), 91-103.

Lobo, J. M., Hortal, J. & Cabrero-Sañudo, F. J. (2006). Regional and local influence of grazing activity on the diversity of a semi-arid dung beetle community. *Diversity and Distributions*, *12*(1), 111-123.

Lobo, J. M., Lumaret, J. P. & Jay-Robert, P. (2002). Modelling the species richness distribution of French dung beetles (Coleoptera, Scarabaeidae) and delimiting the predictive capacity of different groups of explanatory variables. *Global Ecology and Biogeography*, *11*(4), 265-277.

Louzada, J., Lima, A. P., Matavelli, R., Zambaldi, L. & Barlow, J. (2010). Community structure of dung beetles in Amazonian savannas: role of fire disturbance, vegetation and landscape structure. *Landscape ecology*, *25*(4), 631-641.

Lumaret, J. P. & Kirk, A. (1987). Ecology of Dung Beetles In The French Mediterranean Region (Coleoptera: Scarabaeidae). *Acta Zoologica mexicana (ns)*, *19*(24), 1-55.

Lumaret, J. P., Kadiri, N. & Bertrand, M. (1992). Changes in resources: consequences for the dynamics of dung beetle communities. *Journal of Applied Ecology*, 349-356.

Macagno, A. L. M. & Palestrini, C. (2009). The maintenance of extensively exploited pastures within the Alpine mountain belt: implications for dung beetle conservation (Coleoptera: Scarabaeoidea). *Biodiversity and conservation,* 18:3309–3323.

MacArthur, R.H. & Wilson, E.O. (1967). The theory of island biogeography Princenton University Press 224pp.

MacArthur, R.H. (1972). Geographical ecology: patterns in the distribution of species. Harper, New York. 288pp

Mani, M.S. (1956). Entomological Survey of Himalaya Part XXVI, A Contribution to our Knowledge of the Geography of the high altitude of insects of the Nival Zones from the North-West Himalaya Part II. *Journal of Bombay Natural History Society*. *58*(3): 724-748.

Mani, M. S. (1962). Introduction to high altitude entomology: Insect life above the timber-line in the North-West Himalaya. *London: Methuen & Co. pp,* 1-304.

Manel, S., Williams, H. C. & Ormerod S.J. (2001). Evaluating presence–absence models in ecology: the need to account for prevalence. Journal of Applied Ecology, 38, 921- 931.

Martikainen, P., Siitonen, J., Punttila, P., Kaila, L. & Rauh, J. (2000). Species richness of Coleoptera in mature managed and old-growth boreal forests in southern Finland. *Biological conservation*, *94*(2), 199-209.

Matthews, E. G. (1961). A revision of the genus Copris Müller of the western hemisphere (Coleoptera: Scarabaeidae). Revisión del género Copris Müller del hemisferio occidental (Coleoptera, Scarabaeidae). *Entomol. Am*, *41*, 1-139.

Matthews, E.G. (1964). Book reviw (Monographie der Scarabaeidae and Aphodiidae der Palaearktischen und Orientalischen Region, Col. Lamell. (I & II, by V. Balthsar). *Coleopterists Bulletin,* 18 (2): 62-64.

Matthews, E. G. (1971). A revision of the scarabaeine dung beetles of Australia. I. Tribe Onthophagini. *Australian Journal of Zoology Supplementary Series*, *19*(9), 3-330.

Matthews, E. G. (1974). A revision of the scarabaeine dung beetles of Australia. II. Tribe Scarabaeini. *Australian Journal of Zoology Supplementary Series*, *22*(24), 1-211.

Matthews, E.G. (1976) A revision of the scarabaeine dung beetles of Australia. III. Tribe Coprini. Australian Journal of Zoology Supplementary Series, 38, 1–52.

McCoy, E. D. (1990). The distribution of insects along elevational gradients. *Oikos*, 313-322.

McGeoch, M. A., Van Rensburg, B. J. & Botes, A. (2002). The verification and application of bioindicators: a case study of dung beetles in a savanna ecosystem. *Journal of applied ecology*, *39*(4), 661-672.

Menéndez, R., González-Megías, A., Jay-Robert, P. & Marquéz-Ferrando, R. (2014). Climate change and elevational range shifts: evidence from dung beetles in two European mountain ranges. *Global Ecology and Biogeography*, *23*(6), 646-657.

Merow, Cory., Matthew, J. S. & Jr Silander, J. A. (2013). A practical guide to MaxEnt for modeling species' distributions: what it does, and why inputs and settings matter. *Ecography,* 36, 1058–1069, doi: 10.1111/j.1600-0587.2013.07872.x

Mittal, I. C. & Yadava, P. S. (1979). Role of Coprophagous beetles in nutrient cycling. *Geobios*, *6*, 70-73.

Mittal, I. C. (1981). Distributional patterns in Scarabaeidae (Coleoptera): a study on northwest India. *Entomologische Blatter*. *77* (1-2): 75-85.

Mittal, I. C. (1981a). Scarabaeids of Haryana and surrounding areas. *Bulletin of Entomology*, *22*, 35-40.

Mittal, I. C. (1981b). Distributional patterns in Scarabaeidae (Coleoptera): a study on northwest India. *Entomologische Blatter, 77* (1-2): 75-85.

Mittal, I.C. (1984). On the taxonomy of Scarabaeidae (Coleoptera) with a key to India Subfamilies. Entmol Blater, 80 (1): 7-25.

Mittal, I. C. (1986). Dung beetles attracted to human faeces. *Entomologische Blätter*, *82*, 55-64.

Mittal, I. C. (1993). Natural manuring and soil conditioning by dung beetles. *Tropical Ecology*, *34*(2), 150-159.

Mittal, I. C. & Bhati, R. (1998). Food preference of some dung beetles (Coleoptera: Scarabaeidae). *Journal of Entomological Research*, *22*(2), 107-115.

Mittal, I. C. & Vadhera, S. (1998). Succession and community structure in dung-beetles (Coleoptera: Scarabaeidae) in ageing cattle dung. *Journal of Entomological Research*, *22*(3), 253-264.

Mittal, I. C. (1999). Annotated list of scarab fauna (Scarabaeidae: Coleoptera) of western Uttar Pradesh (India). *Annals of Entomology*, *17*(2), 25-43.

Mittal, I. C. (2000). Survey of scarabaeid (Coleoptera) fauna of Himachal Pradesh (India). *Journal of Entomological Research*, *24*(3), 259-269.

Mittal, I. C. (2005). Diversity and conservation status of dung beetles (Laparosticti: Scarabaeidae: Coleoptera) in North India. *Bulletin of National Institute of Ecology*, *15*, 43-51.

Mittal, I. C. & Kakkar, N. (2005). Community dynamics of dung beetles (Scarabaeidae) in a semi-arid region at Kurukshetra in Northern India. *Ecology and Environmental Management: Issues and Research Needs*, *15*, 53-59.

Mittal, I. C. (2011). Synoptic key to Indian species of genus Garreta Janssens (Coleoptera: Scarabaeidae: Scarabaeinae) with a new species from Haryana (India). *Journal of Entomological Research*, *35*(3), 295-298.

Mittal, I.C. & Jain, R. (2015). A checklist of Indian dung beetles (Coleoptera: Scarabaeidae). *Indian Journal of Entomology*, *77*(4), 383-404.

Montes de Oca, E. & Halffter, G. (1998). Invasion of Mexico by two dung beetles previously introduced into the United States. *Studies on Neotropical fauna and Environment*, *33*(1), 37-45.

Mukhi, N. (2002). Population dynamics, Diversity and Community Structure in Dung Beetles (Coleoptera;Scarabaeidae), Ph.D. Thesis, Kurukshetra University, Kurukshetra.

Murphy, H. T. & Lovett-Doust, J. (2004). Context and connectivity in plant metapopulations and landscape mosaics: does the matrix matter?. *Oikos*, *105*(1), 3-14.

Nichols, E., Gardner, T. A., Peres, C. A., Spector, S. & Scarabaeinae Research Network. (2009). Co-declining mammals and dung beetles: an impending ecological cascade. *Oikos*, *118*(4), 481-487.

Nichols, E., Larsen, T., Spector, S., Davis, A. L., Escobar, F., Favila, M., Vulinec, K. & Network, T. S. R. (2007). Global dung beetle response to tropical forest modification and fragmentation: a quantitative literature review and meta-analysis. *Biological conservation*, *137*(1), 1-19.

Nichols, E., Larsen, T., Spector, S., Davis, A. L., Escobar, F., Favila, M. & Vulinec, K. (2007). Global dung beetle response to tropical forest modification and fragmentation: a quantitative literature review and meta-analysis. *Biological conservation*, *137*(1), 1-19.

Nichols, E., Spector, S., Louzada, J., Larsen, T., Amezquita, S., Favila, M. E. & Network, T. S. R. (2008). Ecological functions and ecosystem services provided by Scarabaeinae dung beetles. *Biological conservation*, *141*(6), 1461-1474.

Noriega, J. A. (2012). Dung beetles (Coleoptera: Scarabaeinae) attracted to Lagothrix lagotricha (Humboldt) and Alouatta seniculus (Linnaeus)(Primates: Atelidae) dung in a colombian amazon forest. *Hindawi Publishing Corporation, Psyche,* 1- 6

Noss, R. F. (1990). Indicators for monitoring biodiversity: a hierarchical approach. *Conservation biology*, *4*(4), 355-364.

Numa, C., Lobo, J. M. & Verdu, J. R. (2012). Scaling local abundance determinants in Mediterranean dung beetles. *Insect Conservation and Diversity*, *5*(2), 106-117.

Numa, C., Verdú, J. R., Sánchez, A. & Galante, E. (2009). Effect of landscape structure on the spatial distribution of Mediterranean dung beetle diversity. *Diversity and Distributions*, *15*(3), 489-501.

Nummelin, M. & Hanski, I. (1989). Dung beetles of the Kibale Forest, Uganda; comparison between virgin and managed forests. *Journal of Tropical Ecology*, *5*(3), 349-352.

Nyeko, P. (2009). Dung beetle assemblages and seasonality in primary forest and forest fragments on agricultural landscapes in Budongo, Uganda. *Biotropica*, *41*(4), 476-484.

Paulian R. (1945). Coléoptères Scarabéides de L'Indochine Faune de L'Empire Français ed.Vol.III. Librairie Larose Paris, 1-227.

Peck, S. B. & Howden, H. F. (1984). Response of a dung beetle guild to different sizes of dung bait in a Panamanian rainforest. *Biotropica*, 235-238.

Pearce, J. & Ferrier, S. (2000). Evaluating the predictive performance of habitat models developed using logistic regression. *Ecological Modelling*, *133*, 225-245.

Pearson, R.G., Dawson, T.P., Berry, P.M. & Harrison, P.A. (2002) SPECIES: a spatial evaluation of climate impact on the envelope of species. *Ecological Modelling*, *154*, 289-300.

Pearson, R.G. & Dawson, T.P. (2003) Predicting the impacts of climate change on the distribution of species: are bioclimate envelope models useful? *Global Ecology and Biogeography*, *12*, 361-371.

Pearson, R.G., Dawson, T.P. & Liu, C. (2004) Modelling species distributions in Britain: a hierarchical integration of climate and land-cover data. *Ecography*, *27*, 285-298.

Pearson, R.G., Thuiller, W., Araujo, M.B., Martinez-Meyer, E., Brotons, L., McClean, C., Miles, L., Segurado, P., Dawson, T.P. & Lees, D.C. (2006) Model-based uncertainty in species range prediction. *Journal of Biogeography*, *33*, 1704-1711.

Peterson, A.T., Navarro-Siguenza, A.G. & Benitez-Diaz, H. (1998) The need for continued collecting: a geographic analysis of Mexican bird specimens. *Ibis*, *140*, 288-294.

Peterson, A.T., Soberon, J. & Sanchez-Cordero, V. (1999) Conservatism of ecological niches in evolutionary time. *Science*, *285*, 1265-1267.

Peterson, A.T. (2003a) Predicting the geography of species' invasions via ecological niche modelling. *Quarterly Review of Biology*, *78*, 419-433.

Peterson, A.T. & Shaw, J.J. (2003b) Lutzomyia vectors for cutaneous leishmaniasis in southern Brazil: ecological niche models, predicted geographic distributions, and climate change effects. *International Journal of Parasitology*, 33, 919-931

Phillips, S.J., Anderson, R.P. & Schapire, R.E. (2006). Maximum entropy modelling of species geographic distributions. *Ecological Modelling*, *190*,231-259.

Philips, T. K. (2016). Phylogeny of the Oniticellini and Onthophagini dung beetles (Scarabaeidae, Scarabaeinae) from morphological evidence. *ZooKeys*, (579), 9.

Pianka, E. R. (1966). Latitudinal gradients in species diversity: a review of concepts. *The American Naturalist*, *100*(910), 33-46.

Rajan, P.D. (2006). Insecta: Coleoptera: Scarabaeoidea: Scarabaeidae (Dung Beetles). *In: Zoological Survey of India, Fauna of Bilgiri Rangaswamy Temple Wildlife Sanctuary, Conservation Area Series*, *27*, 91-135.

Ram, S. (2009). Dung beetles (Coleoptera: Scarabaeidae: Coprinae) of Thar Desert of Gujarat. *Occasional Paper-Records of the Zoological Survey of India*, (295).

Ricketts, T. H. (2001). The matrix matters: effective isolation in fragmented landscapes. *The American Naturalist*, *158*(1), 87-99.

Ridsdill-Smith, T. J., Hayles, L. & Palmer, M. J. (1987). Mortality of eggs and larvae of the bush fly, Musca vetustissima Walker (Diptera: Muscidae), caused by scarabaeine dung beetles (Coleoptera: Scarabaeidae) in favourable cattle dung. *Bulletin of Entomological Research*, *77*(4), 731-736.

Ridsdill-Smith, T. J. & Hayles, L. (1990). Stages of bush fly, Musca vetustissima (Diptera: Muscidae), killed by scarabaeine dung beetles (Coleoptera: Scarabaeidae) in unfavourable cattle dung. *Bulletin of Entomological Research*, *80*(4), 473-478.

Roggero, A., Barbero, E. & Palestrini, C. (2015). Phylogenetic and biogeographical review of the Drepanocerina (Coleoptera: Scarabaeidae: Oniticellini) arthropods systematics and phylogeny, *73* (*1*),153-174.

Rohde, K. (1992). Latitudinal gradients in species diversity: the search for the primary cause. *Oikos*, 514-527.

Romero-Alcaraz, E. & Avila, J. M. (2000). Landscape heterogeneity in relation to variations in epigaeic beetle diversity of a Mediterranean ecosystem. Implications for conservation. *Biodiversity & Conservation*, *9*(7), 985-1005.

Rosenlew, H. & Roslin, T. (2008). Habitat fragmentation and the functional efficiency of temperate dung beetles. *Oikos*, *117*(11), 1659-1666.

Roslin, T. & Koivunen, A. (2001). Distribution and abundance of dung beetles in fragmented landscapes. *Oecologia*, *127*(1), 69-77.

.Sabu, T. K., Vinod, K. V. & Vineesh, P. J. (2006). Guild structure, diversity and succession of dung beetles associated with Indian elephant dung in South Western Ghats forests. *Journal of Insect Science*, *6*:17.

Sabu, T. K., Vinod, K. V. & Vineesh, P. J. (2007). Succession of dung beetles (Scarabaeinae: Coleoptera) in the dung pats of gaur, Bos gaurus (Artiodactyla: Bovidae), from the moist deciduous forests of southern Western Ghats. *Biosystematica*, *1*(1), 59-69.

Sabu, T. K., Nithya, S. & Vinod, K. V. (2011a). Faunal survey, endemism and possible species loss of Scarabaeinae (Coleoptera: Scarabaeidae) in the western slopes of the moist South Western Ghats, South India. *Zootaxa*, *2830*(1), 29-38

Sabu, T. K., Vinod, K. V., Latha, M., Nithya, S. & Boby, J. (2011b). Cloud forest dung beetles (Coleoptera: Scarabaeinae) in the Western Ghats, a global biodiversity hotspot in southwestern India. *Tropical Conservation Science*, *4*(1), 12-24.

Saleh, S., Hasanah, U. & Elijonnahdi, E. (2014). Effectiveness of dung beetles as bioindicators of environmental changes in land-use gradient in Sulawesi, Indonesia. *Biotropia-The Southeast Asian Journal of Tropical Biology*, *21*(1), 48-58.

Sa´nchez-Ferna´ndez1, D., Lobo, J. M. & Herna´ndezManrique, O.L. (2011). Species distribution models that do not incorporate global data misrepresent potential distributions: a case study using Iberian diving beetles. *Diversity and Distributions*, *17*, 163-171.

Sato, H. (1997). Two nesting behaviours and life history of a subsocial African dungrolling beetle, Scarabaeus catenatus (Coleoptera: Scarabaeidae). *Journal of Natural History*, *31*(3), 457-469.

Sato, H. & Imamori, M. (1987). Nesting behaviour of a subsocial African ball-roller Kheper platynotus (Coleoptera, Scarabaeidae). *Ecological Entomology*, *12*(4), 415-425.

Schmidt, M. H., Thies, C., Nentwig, W. & Tscharntke, T. (2008). Contrasting responses of arable spiders to the landscape matrix at different spatial scales. *Journal of Biogeography*, *35*(1), 157-166.

Scholtz, C.H. & Chown, S.L. (1995) The evolution of habitat use and diet in the Scarabaeoidea: a phylogenetic approach. Biology, phylogeny, and classification of coleoptera (*ed.J. Pakaluk and S.A. S´ lipinski*), *Museum iInstitut*, *Zoologii PAN, Warsaw*, 355–374.

Scholtz, C.H. & Howden, H.F. (1987a) A revision of the African Canthonina (Coleoptera: Scarabaeidae: Scarabaeinae). *Journal of the Entomological Society of Southern Africa*, *50*, 75-119.

Scholtz, C.H. & Howden, H.F. (1987b) A revision of the southern African genus, Epirinus Reiche (Coleoptera: Scarabaeidae: Scarabaeinae). *Journal of the Entomological Society of Southern Africa*, *50*, 121-154.

Schtickzelle, N., Joiris, A., Van Dyck, H. & Baguette, M. (2007). Quantitative analysis of changes in movement behaviour within and outside habitat in a specialist butterfly. *BMC Evolutionary Biology*, *7*(1), 4.

Schulze, C. H. & Tscharntke, T. (2005). Changes of dung beetle communities from rainforests towards agroforestry systems and annual cultures in Sulawesi (Indonesia). *Biodiversity & Conservation*, *14*(4), 863-877.

Sewak, R. (1985a). Male genitalia of some species of Catharsius Hope (Coleoptera: Scarabaeidae) and its taxonomic importance. *Journal of animal morphology and physiology*, *36*(1-2), 269-271.

Sewak, R. (1985b). On a collection of dung beetles (Coleoptera: Scarabaeidae: Coprinae) from Gujarat, India. *Oiko*, *2*(2), 33-35.

Sewak, R. (1986a). Male genitalia of Indian Onthophagus Latr.(Coleoptera: Scarabaeidae) and its taxonomic importance. *Journal of animal morphology and physiology*, *33*(1-2), 135-140.

Sewak, R. (1986b). On a collection of dung beetles (Coleoptera: Scarabaeidae: Coprinae) from Rajasthan, India. *Oiko*, *3*(1), 11-15.

Sewak, R. (1988). Male genitalia of Indian Oniticellus serville (Coleoptera: Scarabaeidae) and its taxonomic importance. *Journal of animal morphology and physiology*, *35*(2), 165-168.

Sewak, R. (1991). Dung beetles (Coleoptera: Scarabaeidae: Coprinae) from five districts of western Uttar Pradesh. *Oikasay*, *8*(1/2), 25-27.

Sewak, R. (2003). Dung Beetles (Coleoptera: Scarabaeidae: Coprinae) of India with special reference to Arunachal Pradesh, Uttar Pradesh, Gujarat and Rajasthan. *In Advancements in Insect Biodiversity Ed. Rajeeve K. Gupta*, *Agrobios*, Jodhpur: 249-287.

Sewak, R. (2004). Dung beetles (Coleoptera: Scarabaeidae: Coprinae) of India with especial reference to Arunachal Pradesh Uttar Pradesh and Rajasthan. *Advancements in insect biodiversity. Agrobios, Jodhpur*, 249-297.

Sewak, R. (2006). Insecta: Coleoptera: Scarabaeidae: Coprinae (Dung Beetles). *In*: *Zoological Survey of India, Fauna of Arunachal Pradesh. Part 2, Invertebrates. State Fauna Series*, 191-224.

Sewak, R. (2009a). Dung beetles (Coleoptera: Scarabaeidae: Coprinae) of Rajasthan. *Records of the Zoological Survey of India*, *296*, 1-106.

Sewak, R. (2009b). Insecta: Coleoptera: Scarabaeidae: Coprinae (Dung beetles). *In*: *Zoological Survey of India, Faunal Resources of Tal Chhapar Wildlife Sanctuary, Conservation Area Series*, 38: 29-40.

Sewak, R. (2010). Insecta: Coleoptera: Scarabaeidae. *In*: *Zoological Survey of India, Fauna of Ranthambhore National Park, Conservation Area Series*, *43*: 93-118.

Sharp, D. & Muir, F. (1912). XI. The comparative anatomy of the male genital tube in Coleoptera. *Transactions of the Royal Entomological Society of London*, *60*(3), 477-642.

Shepherd, V. E. & Chapman, C. A. (1998). Dung beetles as secondary seed dispersers: impact on seed predation and germination. *Journal of Tropical Ecology*, *14*(2), 199-215.

Slade, E. M. & Roslin, T. (2016). Dung beetle species interactions and multifunctionality are affected by an experimentally warmed climate. *Oikos*, *125*(11), 1607-1616.

Slade, E. M., Mann, D. J. & Lewis, O. T. (2011). Biodiversity and ecosystem function of tropical forest dung beetles under contrasting logging regimes. *Biological Conservation*, *144*(1), 166-174.

Slade, E. M., Mann, D. J. & Lewis, O. T. (2011). Biodiversity and ecosystem function of tropical forest dung beetles under contrasting logging regimes. *Biological Conservation*, *144*(1), 166-174.

Slade, E. M., Mann, D. J. & Lewis, O. T. (2011). Biodiversity and ecosystem function of tropical forest dung beetles under contrasting logging regimes. *Biological Conservation*, *144*(1), 166-174.

Smith, A. B. (2006). A review of the family-group names for the superfamily Scarabaeoidea (Coleoptera) with corrections to nomenclature and a current classification. *The Coleopterists Bulletin*, *60*(mo5), 144-204.

Smith, A. B., Hawks, D. C. & Heraty, J. M. (2006). An overview of the classification and evolution of the major scarab beetle clades (Coleoptera: Scarabaeoidea) based on preliminary molecular analyses. *The Coleopterists Bulletin*, *60*(sp5), 35-47.

Spector, S. (2006). Scarabaeine dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae): an invertebrate focal taxon for biodiversity research and conservation. *The coleopterists bulletin*, *Monograph Number*, 5:71-83

Steenkamp, H. E. & Chown, S. L. (1996). Influence of dense stands of an exotic tree, Prosopis glandulosa Benson, on a savanna dung beetle (Coleoptera: Scarabaeinae) assemblage in southern Africa. *Biological Conservation*, *78*(3), 305-311.

Swets, K. (1988). Measuring the accuracy of diagnostics systems. *Science*. *240*, 1285-1293.

Tarasov, S. I. & Solodovnikov, A. Y. (2011). Phylogenetic analyses reveal reliable morphological markers to classify mega-diversity in Onthophagini dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae). *Cladistics*, *27*(5), 490-528.

Terborgh, J. (1977). Bird species diversity on an Andean elevational gradient. *Ecology*, *58*(5), 1007-1019.

Thakare, V. G., Zade, V. S. & Chandra, K. (2011). Diversity and abundance of scarab beetles (Coleoptera: Scarabaeidae) in Kolkas Region of Melghat Tiger Reserve (MTR), District Amravati, Maharashtra, India. *World Journal of Zoology*, *6*(1), 73-79.

Thomson, S. A., Pyle, R. L., Ahyong, S. T., Alonso-Zarazaga, M., Ammirati, J., Araya, J. F. & Baker, W. J. (2018). Taxonomy based on science is necessary for global conservation. *PLoS biology*, *16*(3), e2005075.

Tocco, C., Balmer, J. P. & Villet, M. H. (2018). Trophic preference of southern African dung beetles (Scarabaeoidea: Scarabaeinae and Aphodiinae) and its influence on bioindicator surveys. *African journal of ecology*, *56*(4), 938-948.

Tonelli, M., Verdú, J. R. & Zunino, M. (2018). Effects of the progressive abandonment of grazing on dung beetle biodiversity: body size matters. *Biodiversity and conservation*, *27*(1), 189-204.

Tregidgo, D. J., Qie, L., Barlow, J., Sodhi, N. S., & Lim, S. L. H. (2010). Vertical stratification responses of an arboreal dung beetle species to tropical forest fragmentation in Malaysia. *Biotropica*, *42*(5), 521-525.

Treitler, J. T., Buse, J., Carpaneto, G. M., Zerbe, S. & Mantilla-Contreras, J. (2017). Effects of dung-pad conditions and density on coprophagous beetle assemblages in a Mediterranean rangeland. *Biodiversity and Conservation*, *26*(6), 1431-1444.

Topping, C.J. and Sunderland, K.D. (1992). Limitations to the use of pitfall traps in ecological studies exemplified by study of spiders in a field of winter wheat. *Journal of Applied Ecology*. *29*, 485-491.

Uniyal, V.P., Quasin, S. and R. Ganguli. 2010. Kailash Sacred Landscape Feasibility Report (Mammals, Birds and Invertebrates). Wildlife Instutute of India, Dehra Dun 54p.

Urrea-Galeano, L. A., Andresen, E., Coates, R., Mora Ardila, F. & Ibarra-Manríquez, G. (2019). Dung beetle activity affects rain forest seed bank dynamics and seedling establishment. *Biotropica*, *51*(2), 186-195.

Van Rensburg, B. J., McGeoch, M. A., Chown, S. L. & Van Jaarsveld, A. S. (1999). Conservation of heterogeneity among dung beetles in the Maputaland Centre of Endemism, South Africa. *Biological Conservation*, *88*(2), 145-153.

Veldhuis, M. P., Gommers, M. I., Olff, H. & Berg, M. P. (2018). Spatial redistribution of nutrients by large herbivores and dung beetles in a savanna ecosystem. *Journal of Ecology*, *106*(1), 422-433.

Venugopal, K. S., Thomas, S. K. & Flemming, A. T. (2012). Diversity and community structure of dung beetles (Coleoptera: Scarabaeinae) associated with semi-urban fragmented agricultural land in the Malabar coast in southern India. *Journal of Threatened Taxa*, 2685-2692.

Verdú, J. R. Crespo, M. B. & Galante, E. (2000). Conservation strategy of a nature reserve in Mediterranean ecosystems: the effects of protection from grazing on biodiversity. *Biodiversity & Conservation*, *9*(12), 1707-1721.

Verdú, J. R. & Galante, E. (2002). Climatic stress, food availability and human activity as determinants of endemism patterns in the Mediterranean region: the case of dung beetles (Coleoptera, Scarabaeoidea) in the Iberian Peninsula. *Diversity and Distributions*, *8*(5), 259-274.

Verdú, J. R. Arellano, L., Numa, C. & Micó, E. (2007). Roles of endothermy in niche differentiation for ball-rolling dung beetles (Coleoptera: Scarabaeidae) along an altitudinal gradient. *Ecological Entomology*, *32*(5), 544-551.

Verdú, J. R., Moreno, C. E., Sánchez-Rojas, G., Numa, C., Galante, E. & Halffter, G. (2007). Grazing promotes dung beetle diversity in the xeric landscape of a Mexican Biosphere Reserve. *Biological Conservation*, *140*(3-4), 308-317.

Villalba, S., Lobo, J. M., Martín-Piera, F. & Zardoya, R. (2002). Phylogenetic relationships of Iberian dung beetles (Coleoptera: Scarabaeinae): insights on the evolution of nesting behavior. *Journal of molecular evolution*, *55*(1), 116-126.

Vulinec, K. (2002). Dung Beetle Communities and Seed Dispersal in Primary Forest and Disturbed Land in Amazonia1. *Biotropica*, *34*(2), 297-309.

Williams, C.B. (1936). The influence of moonlight on the activity of certain nocturnal insects, particularly of the family of Noctuidae as indicated by light-trap. *Philosophical Transactions of the Royal Society B-Biological Sciences. 226*, 357-389.

WII. (2010). KSLCDI Feasibility assessment report, India. Submitted to GBPIHED, Almora. 67p.

Wolda, H. (1987). Altitude, habitat and tropical insect diversity. *Biological Journal of the Linnean Society*, *30*(4), 313-323.

Woodcock, B. A., Pywell, R. F., Roy, D. B., Rose, R. J. & Bell, D. (2005). Grazing management of calcareous grasslands and its implications for the conservation of beetle communities. *Biological Conservation*, *125*(2), 193-202.

Yela, J. L. & Holyoak, M. (1997). Effects of moonlight and meteorological factors on light and bait trap catches of Noctuid moths (Lepidoptera: Noctuidae). *Environmental Entomology*. *26* 1283-1290.

Zunino, M. (1972). Revisione delle specie paleartiche del genere *Onthophagus* Latr. (Coleoptera Scarabaeoidea).I. Il sottogenere

Euonthophagus Balth. *Bolletino del Museo di Zoologia dell' Universitàdi Torino*, 1, 1-28.

Zunino, M. (1978). L'armatura genitale negli Onthophagini: tecniche di preparazione e criteri di studio (Coleoptera Scarabaeoidea). L'informatore del giovane entomologo. *Supplemento al Bollettino dellaSocietà Entomologica Italiana*, *90*, 21-26.

Zunino, M. (1979). Gruppi artificiali e gruppi naturali negli Onthophagus (Coleoptera: Scarabaeoidea). *Bolletino del Museo di Zoologia dell' Universitàdi Torino*, *1*, 1-18.

Zunino, M. (1983). Essai préliminaire sur l'évolution des armures génitales des Scarabaeinae, par rapport à la taxonomie du groupe et à l'évolution du comportement de nidification [Col. Scarabaeidae]. *Bulletin de la Societe entomologique de France*, *88*(7), 531-542.

Zunino, M. (1987). La evolución de los aparatos copuladores: comentarios a W. G. Eberhard, "Sexual selection and animal genitalia". *Elytron*, *1*, 105-107

Zunino, M. & Halffter, G. (1988). Análisis taxonómico, ecológico y biogeográfico de un grupo Americano de Onthophagus (Coleoptera: Scarabaeidae). Monografie del Museo Regionale di Scienze Naturali, Torino, *9*, 1-211.

Zunino, M. & Palestrini, C. (1988). L'evoluzione differenziale dei caratteri e il riconoscimento delle specie nei Coleotteri Scarabeidi, In: P. Omodeo, P. Burighel & P. Tongiorgi (Eds.). Il problema biologico della specie. Mucchi, Modena. 173-176.

Zunino, M. & Halffter, G. (1997). Sobre Onthophagus Latreille, 1802 Americanos (Coleoptera: Scarabaeidae: Scarabaeinae). *Elytron*, *11*, 157-178.

Zunino, M. (2012). Cuarenta años de anatomía de las piezas genitales en la taxonomía de los escarabajos (Coleoptera: Scarabaeoidea): el estado del arte. Dugesiana, *18*, 197-206.

http://cran.r-project.org

List of Workshops/Conference/Trainings

1. Presented a research paper entitled "Role of Insects in ecosystem services and ecological Functions" in Uttrakhand State, Science and Technology Congress, Dehradun from 26th to 28th February 2015.
2. Participated in training course on Mainstreaming Biodiversity in Road and Rail Transportation Projects for Promoting Smart Green Infrastructure at Wildlife Institute of India, Dehradun from 17th to 19th march 2016.
3. Presented a research work entitled insects: A focal taxa for long term ecological monitoring in Kailash Sacred Landscape, Pithoragarh, Uttrakahand, India on 23 Sep 2016 at Wildlife Institute of India, Dehradun.
4. Presented a research work entitled "Impact of Forest Fire on Invertebrates, Reptiles and Avifaunal Diversity in Lansdowne Forest Division: A preliminary assessment" at Wildlife Institute of India, Dehradun, 2017.
5. Presented a research work entitled "Assessment and Conservation Practices of Pollinators through Community Participation in the Indian Trans Himalayan Region: Climate Change Perspective" at Wildlife Institute of India, Dehradun 2018.
6. Participated in a summer school organized by University of Innsbruck, Austria from 1st to 17th September 2019.
7. Presented a research paper entitled "Dung beetles as indicator taxa for long-term ecological monitoring in mountainous ecosystems, Kailash Sacred Landscape, Western Himalaya, India" in International Mountain Conference 2019, University of Innsbruck, Austria.
8. Chauhan, Mona and Uniyal, V.P. (2019). Presented a research paper in "Regional expert's symposium on ecosystem-based adaptation in the Hindu Kush Himalaya" from 17-19 Dec 2019 in Chengdu, Sichuan Province, People's Republic of China.

List of publications

1. Chauhan, M. & Uniyal, V.P. (2017). Dung Beetles (Scarabaeidae): An Efficient Model for Long Term Ecological Monitoring. Indian Forester. 143(10): 1088-1090.
2. Uniyal, V.P. & Chauhan, M. (2018). Monitoring sites in pilot sites of Kailash Sacred Landscape- India, *In Rawat, G.S & Gopi, G.V. Manual for comprehensive environmental socio-economic monitoring in Kailash Sacred Landsacpe India*, Wildlife Institute of India, ISBN 81-85496-30-7, 195pp.
3. Chauhan, M. & Uniyal, V.P. (2019). Preliminary Assessment of Invertebrate's diversity in Lansdowne Forest Division, Uttarakhand. (Book chapter). Himalayas: Ecology, Resources, Development and Conflict.

Appendix – **4.1 List of sampling locations in Kailash Sacred Landscape, Pithoragarh, India**

S. No.	LOCATIONS	LATITUDE	LONGITUDE
1.	Askora	29.55297	80.057113
2.	Awlaghat	29.63733879	80.12589589
3.	Baling	30.2072407	80.55287793
4.	Bans	2936837	8008383
5.	Baram	29.85016759	80.35684108
6.	Basantkot	30.08567262	80.27337012
7.	Bastey	29.59923	80.12655
8.	Bhauri	29.65717	80.24789
9.	Bhetsera	29.661412	80.235066
10.	Bilju	30.39539023	80.16435209
11.	Bon	30.24241233	80.55699846
12.	Bothi	30.08110507	80.3035964
13.	Boyal	29.664953	80.124464
14.	Bungapani	29.95611459	80.30324585
15.	Burphu	30.36839522	80.18050507
16.	Chal	30.17847831	80.582981
17.	Chalmachilaso	29.97340844	80.64873033
18.	Channapandey	29.61845216	80.18385331
19.	Cheda	29.625019	80.19106
20.	Chhoribagad	29.947114	80.299129
21.	Chingari	29.47168	80.22085
22.	Chitgal	29.66460152	80.07680801
23.	Dantu	30.25322509	80.54107267
24.	Dar Pangu	29.99036437	80.63050354
25.	Dar	30.07133047	80.60397721
26.	Daranti	30.09068704	80.25126623
27.	Dharari	29.63196887	80.00219552
28.	Dharchula	29.84534958	80.5332538
29.	Digtoli	29.63162465	80.15683383
30.	Dugtu	30.24899347	80.54579408
31.	Dungari	29.585076	80.144104
32.	Dutibagarh	29.75611111	80.38025
33.	Futsil Pine	29.677002	80.06283892
34.	Galati	29.84057161	80.52962229
35.	Gangashiri	29.65356	80.25326
36.	Gangolihat	29.65729288	80.03823801
37.	Gaurihat	29.571885	80.35968
38.	Goe	30.26233279	80.54024103
39.	Gogana	29.501779	80.138246
40.	Gurura	29.62093027	80.17718144
41.	Haldu	29.467896	80.286118

42.	Harkot	30.05529722	80.24662222
43.	Himkhola	30.00508823	80.63284504
44.	Himtara	29.48476	80.1956
45.	Jajrauli	29.61377341	80.13224249
46.	Jamrari	29.49759	80.14156
47.	Jamtari	29.480334	80.284434
48.	Jartola	29.531558	80.086799
49.	Jeoljibi	29.75130161	80.38465298
50.	Jhoolaghat	29.557474	80.357419
51.	Kafaldungri	29.60415433	80.14284747
52.	Kalamuni	30.02912832	80.20048437
53.	Kalsinkatiya	29.61439	80.156208
54.	Kanjoti	30.01760426	80.57064363
55.	Khaliya	30.06807119	80.20846165
56.	Khatigaon	29.61452	80.126061
57.	Khilach	30.30290514	80.21375461
58.	Kuerban	29.45209	80.23697
59.	Kuntola	29.630896	79.98047
60.	Kute	29.508126	80.286667
61.	Laali	29.659696	80.03732447
62.	Lamkeshwar	29.7112866	80.02067647
63.	Laspa	30.28554237	80.20233035
64.	Lumati	29.89350504	80.31708791
65.	Lwa	30.34269553	80.19169363
66.	Madkote	30.05606008	80.29457441
67.	Majirkanda	29.576356	80.348065
68.	Martoli	30.35175945	80.19507191
69.	Milam	30.44009788	80.12731979
70.	Mostmanu	29.61935742	80.19654643
71.	Munakot	29.570622	80.291601
72.	Munsiyari	30.06488611	80.23454722
73.	Nagling	30.18066452	80.56960297
74.	Naini	29.62730609	80.1478718
75.	Nakote	29.60585523	80.1741735
76.	Nrayan Ashram	29.97021287	80.65372817
77.	Okhal	29.48325	80.24472
78.	Pabhe	29.59526914	80.14711098
79.	Pacchu	30.40470114	80.15143652
80.	Pangu	29.98957944	80.61861436
81.	Patalbhuwneshwar	29.688402	80.092233
82.	Rameshwar	29.519812	80.104709
83.	Rangal	29.64305693	79.99114386
84.	Ratura	29.562523	80.04765
85.	Rawal	29.65754906	80.04713348
86.	Rilkot	30.31939675	80.2106429

87.	Sawalisera	29.75042701	80.35691478
88.	Sela	30.14773338	80.60649419
89.	Sellsalla	29.4517	80.23671
90.	Sheraghat	30.01102364	80.31946666
91.	Silgiya	29.47926	80.23766
92.	Sintoli	29.61227528	80.1673616
93.	Sipu	30.30145289	80.49564564
94.	Sobla	30.06723675	80.57133773
95.	Sorlekh	29.61162839	80.28541218
96.	Syunsi	29.63626	80.25354
97.	Thala	29.535847	80.148935
98.	Tidang	30.27538007	80.52859797
99.	Timalpata	29.6474	80.24117
100.	Tola	30.33525872	80.21286313
101.	Tolli	29.81639223	80.36548172
102.	Tulakhand	29.562523	80.04765
103.	Wadda	29.56683	80.2755

Appendix – 5.1

List of dung beetles documented from KSL, India

Family Scarabaeidae Latreille, 1802	
Subfamily Scarabaeinae Latreille, 1802	
	Tribe Gymnopleurini Lacordaire, 1856
	Genus ***Gymnopleurus*** Illiger, 1803
1.	*Gymnopleurus cyaneus* Fabricius, 1798
	Genus ***Paragymnopleurus*** Shipp, 1897
2.	*Paragymnopleurus sinuatus assamensis* Waterhouse, 1890
	Tribe Sisyphini Mulsant, 1842
	Genus ***Sisyphus*** Latreille, 1807
3.	*Sisyphus (Sisyphus) longipes* (Olivie r, 1789)
4.	*Sisyphus (Sisyphus neglectus* Gory, 1833
	Tribe Coprini Leach, 1815
	Genus ***Catharsius*** Hope, 1837
5.	*Catharsius molossus* (Linnaeus, 1758)
6.	*Catharsius pithecius* (Fabricius, 1775)
7.	*Catharsius sagax* (Quenselt, 1806)
	Genus ***Copris*** Müller, 1764
8.	*Copris repertus* Walker, 1858
9.	*Copris sarpedon* Harold, 1868
	Genus ***Paracopris*** Balthasar, 1939
10.	*Copris (Paracopris) excisus* Waterhouse, 1891
11.	*Copris (Paracopris) surdus* Arrow, 1931
	Tribe Oniticellini Kolbe, 1905
	Subtribe Drepanocerina van Lansberge, 1875
	Genus ***Tibiodrepanus*** Krikken, 2009
12.	*Tibiodrepanus setosus* (Wiedmann, 1823)
	Subtribe Oniticellina Kolbe, 1905
	Genus ***Euoniticellus*** Janssens, 1953

13.	*Euoniticellus pallipes* (Fabricus, 1781)
14.	*Euoniticellus pallens* (Olivier, 1789)
	Genus ***Liatongus*** Reitter, 1893
15.	*Liatongus gagatinus* (Hope, 1831)
16.	*Liatongus mergacerus* (Hope, 1831)
17.	*Liatongus phanaeoides* (Westwood, 1839)
	Genus ***Oniticellus*** Dejean, 1821
18.	*Oniticellus cinctus* (Fabricius, 1775)
	Genus ***Tiniocellus*** Péringuey, 1900
19.	*Tiniocellus spinipes* (Roth, 1851)
	Tribe **Onitini** Laporte, 1840
	Genus ***Onitis*** Fabricius, 1798
20.	*Onitis excavatus* Arrow, 1931
21.	*Onitis falcatus* (Wulfen, 1786)
22.	*Onitis philemon* Fabricius, 1801
23.	*Onitis subopacus* Arrow, 1931
24.	*Onitis virens* Lansberge, 1875
	Tribe Onthophagini Burmeister, 1846
	Genus ***Caccobius*** Thomson, 1859
	Subgenus ***Caccobius*** Thomson, 1859
25.	*Caccobius (Caccobius) denticollis* Harold, 1867
	Subgenus ***Caccophilus*** Jekel, 1872
26.	*Caccobius (Caccophilus) diminutivus* Walker, 1858
27.	*Caccobius (Caccophilus) unicornis* (Fabricius, 1798)
	Genus ***Cleptocaccobius*** Cambefort, 1984
28.	*Cleptocaccobius inermis* (Arrow, 1931)
	Genus ***Digitonthophagus*** Balthasar 1959
29.	*Digitonthophagus bonasus* (Fabricius, 1775)
	Genus ***Onthophagus*** Latreille, 1802
	Subgenus ***Colobonthophagus*** Balthasar, 1963
30.	*Onthophagus (Colobonthophagus) dama* (Fabricius, 1798)
31.	*Onthophagus (Colobonthophagus) quadridentatus* Fabricus, 1798

32.	*Onthophagus (Colobonthophagus) hindu* Arrow, 1931
33.	*Onthophagus (Colobonthophagus) ramosellus* Bates, 1891
34.	*Onthophagus (Colobonthophagus) ramosus* (Wiedemann, 1823)
	Subgenus ***Matashia***
35.	*Onthophagus (Onthophagus) (Matashia) kuluensis* Bates, 1891
	Subgenus ***Indonthophagus***
36.	*Onthophagus (Indonthophagus) hastifer* Lansberge, 1885
37.	*Onthophagus (Indonthophagus) mopsus* (Fabricius, 1792)
	Sub genus Phanaeomorphus
38.	*Onthophagus (Phanaeomorphus) gagates* Hope, 1831
	Sub genus Serrophorus
39.	*Onthophagus (Serrophorus) rectecornutus Lansberge, 1883*
	***Onthophagus*incertaesedis**
40.	*Onthophagus (Onthophagus) abreui* Arrow, 1931
41.	*Onthophagus (Onthophagus) cervus* (Fabricius, 1798)
42.	*Onthophagus (Onthophagus) compactus* Arrow, 1933
43.	*Onthophagus (Onthophagus) furcillifer* Bates, 1891
44.	*Onthophagus (Onthophagus) griseosetosus* Arrow, 1931
	Genus *Proagoderus*
45.	*Proagoderus pactolus* (Fabricius, 1787)
	Unidentified up to subfamily level
46.	*Scarabaeinae sp.* 1
47.	*Scarabaeinae sp.* 2
48.	*Scarabaeinae sp.* 3
49.	*Scarabaeinae sp.* 4

Appendix – **6.1**

Different habitat for indicator species analysis

Habitat Type	**Habitat Code**
Agriculture at lower elevation	AG
Agriculture Land at higher elevation	MG
Alpine Meadows	BG
Banj Oak Forest	OF
Blue Pine Forest	BP
Celtis Forest	CL
Cheyura Forest	CF
Cypress Forest	CF
Deodar Forest	DF
Grassland	GL
High Altitude *Firabies spectalis*	HAF
Human Habitation at higher elevation	HHH
Human Habitation at lower elevation	HH
Kharsu Oak Forest	OK
Mixed Forest at higher elevation	HMF
Mixed Forest at lower elevation	MF
Pine Forest	PF
Rhododendron arboratum Forest	RA
Rhododendron barbatum Forest	RB
Sal Forest	SF
Scrubland at Higher Elevation	HSC
Scrubland at Lower Elevation	SC
Taxus baccata Forest	TB
Thuner Forest	TH
Utis Forest	UT

***Appendix* – 7.1**

List of species for Maximum Entropy distribution modelling

Family Scarabaeidae Latreille, 1802	
Subfamily Scarabaeinae Latreille, 1802	
	Tribe Sisyphini Mulsant, 1842
	Genus ***Sisyphus*** Latreille, 1807
1.	*Sisyphus (Sisyphus) longipes* (Olivie r, 1789)
2.	*Sisyphus (Sisyphus neglectus* Gory, 1833
	Tribe Coprini Leach, 1815
	Genus ***Catharsius*** Hope, 1837
3.	*Catharsius molossus* (Linnaeus, 1758)
	Tribe Oniticellini Kolbe, 1905
	Subtribe Oniticellina Kolbe, 1905
	Genus ***Liatongus*** Reitter, 1893
4.	*Liatongus gagatinus* (Hope, 1831)
5.	*Liatongus mergacerus* (Hope, 1831)
6.	*Liatongus phanaeoides* (Westwood, 1839)
	Genus ***Oniticellus*** Dejean, 1821
7.	*Oniticellus cinctus* (Fabricius, 1775)
	Genus ***Tiniocellus*** Péringuey, 1900
	Tiniocellus spinipes (Roth, 1851)
	Tribe **Onitini** Laporte, 1840
	Genus ***Onitis*** Fabricius, 1798
8.	*Onitis falcatus* (Wulfen, 1786)
9.	*Onitis philemon* Fabricius, 1801
10.	*Onitis subopacus* Arrow, 1931
	Tribe Onthophagini Burmeister, 1846
	Genus ***Caccobius*** Thomson, 1859
	Subgenus ***Caccobius*** Thomson, 1859
11.	*Caccobius (Caccobius) denticollis* Harold, 1867

	Genus ***Onthophagus*** Latreille, 1802
	Subgenus ***Colobonthophagus*** Balthasar, 1963
12.	*Onthophagus (Colobonthophagus) dama* (Fabricius, 1798)
13.	*Onthophagus (Colobonthophagus) ramosellus* Bates, 1891
	Subgenus ***Indonthophagus***
14.	*Onthophagus (Indonthophagus) hastifer* Lansberge, 1885
	Subgenus ***Phanaeomorphus***
15.	*Onthophagus (Phanaeomorphus) gagates* Hope, 1831
	Onthophagus**incertaesedis**
16.	*Onthophagus (Onthophagus) abreui* Arrow, 1931

Indian Forester, 143 (10) : 1088-1090, 2017
http://www.indianforester.co.in
ISSN No. 0019-4816 (Print)
ISSN No. 2321-094X (Online)

(IV)

DUNG BEETLES (SCARABAEIDAE): AN EFFICIENT MODEL FOR LONG TERM ECOLOGICAL MONITORING

Ecological monitoring can provide advanced warning of undesirable ecological change (climate change, forest fragmentation and biodiversity loss) thus permit managers and policy makers to adopt an adaptive management approach to conserving biological diversity. The nature of landuse changes in recent decades has not only resulted in a dramatic decrease in total forest cover, but also accelerated biodiversity loss and forest fragmentation. Forest fragmentation is an important process contributing to the present-day concern over the loss of biodiversity and rates of species extinction. There is now an urgent need to identify the key effects of forest fragmentation on biotic systems and to find management solutions, for this ecological monitoring is very important to understand the complex process of biodiversity loss. Bioindicators have been proven to be useful tools for monitoring and detecting changes in the environment. Bioindicator can be defined as a species or group of species that readily reflects the impact of environmental change on habitat, community or ecosystem or is the indicative of the diversity of a subset of taxa or the whole biodiversity within an area. Especially, living things are so closely related to the environment that the indicator between the environment and living things shows close interrelationship. Also, the indicator related to environment provides information about representative or decisive environmental phenomenon and is used to simplify complicated facts (Noss, 1990: Dufrene and Legendre, 1997; Mcgeoch *et al.,* 2002; Han *et al.,* 2015). It is impossible to evaluate the total biodiversity and also to measure the impact of environmental change on each and every species therefore we need efficient model system for analyzing the concern. Dung beetles provide an effective model to understand the effect of environmental change, habitat fragmentation or any stress.

Dung beetles (Scarabaeidae) compose widely distributed taxa; about 5000 species (Scholtz *et al.,* 2009) are present worldwide. Dung beetles are divided into three functional groups: rollers, tunnelers and dwellers, which largely feed on dung and carrion. Dung beetles perform various ecological functions in diverse ecological services (Nichols *et al.,* 2008) such as dung removal, nutrient cycling, bioturbation, secondary seed dispersal and parasitic control which are very useful to maintain ecosystem integrity. Community structure of dung beetles is largely affected by forest modification, fragmentation and elevated anthropogenic pressure hence this group clearly reflects the impact of anthropogenic pressure and habitat alteration. Community structure, population of dung beetles can be rapidly determined using simple, standardized, time and cost effective trapping methods which permits efficient comparative evaluation of ecological changes at landscape scale.

Dung beetles as bio-indicator across landscape matrix

Dung beetles have been used in empirical studies (Klein, 1989; Davis *et al.,* 2001, 2008; Gardner *et al.,* 2008) to evaluate the biodiversity loss, forest fragmentation and the impact of habitat modification. The structure, organization and composition of guild structure of dung beetles primary forest are totally different from the fragmented forests and also a transition guild is also present in ecotones which have its own structure (Halffter and Favila, 1993). Changes in dung beetle assemblage structure are correlated with climatic and/or edaphic variables, which clearly interact to drive biogeographical composition and population responses of dung beetle species across regional and local gradients. Studies (Estrada *et al*.,1998; Numa *et al.,* 2009, 2012; Shahabuddin *et al.,* 2014; Batista *et al.,* 2016) showed that the existence of a rich pool of forest dung beetles species exist in the fragmented landscape but the majority of the species are represented in low numbers. Species richness, abundance, and biomass declined drastically on smaller and more isolated islands (Larsen *et al.,* 2008). Fragment characteristics such as vegetation structure, ground cover, litter depth, age, and isolation distance also influence dung beetle assemblage in forest. Due to the modification in tree cover or canopy cover, native forest species undergo local extinction and are replaced by open area species (Halffter and Arelleno, 2002). Canopy cover is thought to be influence humidity as well as atmospheric and soil surface temperature, which might affect the survival and reproduction of dung beetles, as well as food availability and attractiveness. Edge effects also considered as an important factor in the distribution and composition of dung beetles communities as abundance, species richness and species composition of dung beetles changed with distance from roads/trails Forest edges act as a barrier and affect the patterns of dispersal and spatial distribution of dung beetles communities. Narrow or small forest clearings for skid trails, logging roads, log yards, and logging camps affect local distributions of dung beetles. Litter has been reported to be important for modifying soil characteristics such as moisture, density, and nutrient load, which may increase the recruitment and/or reproduction of dung beetles. Changes in land management practices such as pastures replaced by arboreal crops results the replacement of a rich assemblage of native species by introduced species just as *Digithonthophagus gazella*, a savanna specialist, that has been expanding its range southward from the United States in part as a result of conversion of large extension of rain forest to pastures (De Oca and Halffter, 1998). Escobar *et al.* (2007) evaluated the effect of expanded cattle ranching along three altitudinal gradient in one located in the Mexican Transition Zone and two located in northern Andes. All three sites are facing immense pressure of not only dairy farming but also expansion of mountain into agricultural areas. They reported that processes of disturbance caused by human activity along altitudinal gradients can impact communities in different ways, depending on the geographic position of each mountain and particularly the biogeographical history of the group of species that inhabits it. Drawing upon historical data, comparisons among dung beetle collections across parts of Africa and the Mediterranean provide circumstantial evidence of strong, linked changes in mammal-dung beetle assemblages, typically within a context of broader land-use change (Nichols *et al.,* 2009). Lobo *et al.* (2002) also analyzed which factor or factors govern the species richness and distribution of dung beetles of France mainland and Corsica Island. Six climate variables were utilized mean annual temperature, temperature variation, maximum mean temperature, minimum mean temperature, mean annual precipitation and precipitation variation. Results showed that Minimum mean temperature is the most influential variable on a local scale, while maximum and mean temperature are the most important spatially structured variables. In Europe Menendez *et al.* (2014) compared historical and current data on dung beetle distributions along elevation gradients for 30 species in the South-western Alps (France) and 19 species in the Sierra Nevada (Spain) and reported that up-slope range shifts for 63% and 90% of the species in the SW Alps and Sierra Nevada, respectively. The magnitudes of range shifts were consistent with the level of warming experienced in each region, but they also reflected the asymmetrical warming observed along the elevation gradients. This study reveals that climate change is directly or indirectly responsible for range-shift of the species. Anthropogenic land use and habitat fragmentation clearly promote community level taxonomic divergence in human modified landscapes. This community level taxonomic divergence suggests that edge-dominated and matrix habitats ensure the persistence of disturbance adapted species, some of which exclusively in these habitats, which are unsuitable for forest dependent species (Filgueiras *et al.,* 2016).

New paradigms in conservation biology propose that not only protected areas but also patches of natural habitat via corridors should be analyzed in the context of the agricultural or managed matrix. Land use patterns significantly affect the species assemblages, diversity, and richness and also guild structure across various habitats. We need long-term observations and basic ecological studies to assess the impact of land management practices. The success of using dung beetles is based on cost-effective data collection, sensitivity to different environmental factors and wide habitat requirements. Species richness, abundance of dung beetles varies widely depending on the period of the year, habitat, seasonality, rain fall and land use practices. Forest fragmentation has strong negative consequences on dung beetle biodiversity. Environmental changes also have considerable influence on the community structure of dung beetles. Bioindicator based approach to ecological monitoring is crucial for developing countries largely having complicated landscape matrix as it includes protected areas, dominated agriculture system and patchy habitats. Ecological data on population structure, community composition, habitat specificity of dung beetles correlated with biogeographic and historical data can be efficient model to analyze the impact of human induced changes in forest along different land use gradient, climate change and forest fragmentation.

References

Filgueiras K.C.B., Tabarelli M., Leal R.I., Vaz-de-Mello Z.F., Peres C.A. and Luciana Iannuzzi L. (2016). Spatial replacement of dung beetles in edge-affected habitats: biotic homogenization or divergence in fragmented tropical forest landscapes?. *Diversity and Distributions,* 22:400-409

Batista M.C., Lopes G.S., Marques P.J.L. and Teodoro V.A. (2016).The dung beetle assemblage (Coleoptera: Scarabaeinae) is differently affected by land use and seasonality in northeastern Brazil. *Entomotropica,* 31(13):95-104

De Oca M.E. and Halffter G. (1998). Invasion of Mexico by Two Dung Beetles Previously Introduced Into the United States. *Studies on Neotropical Fauna and Environment,* 33:37-45

Davis A.J., Holloway J.D., Huijbregts H., Kirk-Spriggs A.H. and Sutton S.L. (2001). Dung beetles as indicators of change in the forests of northern Borneo. *J. Applied Ecology,* 38:593-161

Davis A.L.V., Scholtz C.H. and Deschodt C. (2008). Multi-scale determinants of dung beetle assemblage structure across abiotic gradients of the Kalahari-Nama Karoo ecotone, South Africa. *J. Biogeography,* 35:1465-1480

Dufrene M. and Legendre P. (1997). Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecological Monographs,* 67:345-366

Estrada A., Coates-Estrada R., Dadda A.A. and Cammarano P. (1998). Dung and carrion beetles in tropical rain forest fragments and agricultural habitats at Los Tuxtlas, Mexico. *J. Tropical Ecology,* 14:577-593

Escobar F., Halffter G. and Arellano L. (2007). From forest to pasture: an evaluation of the influence of environment and biogeography on the structure of dung beetle (Scarabaeinae) assemblages along three altitudinal gradients in the Neotropical region. *Ecography,* 30:193-208

Gardner T.A., Barlow J., Araujo I.S., Avila-Pires T.C., Bonaldo A.B., Costa J.E., Esposito M.C., Ferreira L.V., Hawes J., Hernandez M.I., Hoogmoed M.S., Leite R.N., Lo-Man-Hung N.F., Malcolm J.R., Martins M.B., Mestre L.A., Miranda-Santos R., Overal W.L., Parry L., Peters S.L., Ribeiro-Junior M.A., da Silva M.N., da Silva M.C. and Peres C.A. (2008). The cost-effectiveness of biodiversity surveys in tropical forests. *Ecological Letters,* 11:139-150

Halffter G. and Favila M.E. (1993). The Scarabaeinae (Insecta: Coleoptera) an animal group for analyzing, inventorying, and monitoring biodiversity in tropical rainforest and modified landscapes. *Biology International,* 27:15-21

Halffter G. and Arellano L. (2002) Response of dung beetle diversity to human-induced changes in a tropical landscape. *Biotropica,* 34:144-154

Han Y., Kwon O. and Cho Y. (2015). A study of bioindicator selection for long-term ecological monitoring. *Journal of Ecology and Environment,* 38(1):119-122

Klein B.C. (1989). Effects of forest fragmentation on dung and carrion beetle communities in central Amazonia. *Ecology,* 70:1715-1725

Larsen T.H., Lopera A. and Forsyth A. (2008). Understanding trait-dependent community disassembly: dung beetles, density functions, and forest fragmentation. *Conservation Biology,* 22(5):1288-1298

Lobo M. J., Lumaret J. and Jay-Robert P. (2002). Diversity, distinctiveness and conservation status of the Mediterranean coastal dung beetle assemblage in the regional natural park of the Camargue (France). *Diversity and Distributions,* 7(6):257-270

Mcgeoch M.A., Van Rensburg B.J. and Botes A. (2002). The verification and application of bioindicators: a case study of dung beetles in a savanna ecosystem. *J. Applied Ecology,* 39:661-672

Montes de Oca E. and Halffter G. (1998). Invasion of Mexico by Two Dung Beetles Previously Introduced into the United States. *Studies on Neotropical Fauna and Environment,* 33:37-45

Menéndez R., González-Megías A., Jay-Robert P. and Marquéz-Ferrando R. (2014). Climate change and elevational range shifts: evidence from dung beetles in two European mountain ranges. *Global Ecology and Biogeography*, 23:646-657.

Nichols E., Spector S., Louzada J., Larsen T., Amezquitad S. and Favila M.E. (2008). Ecological functions and ecosystem services provided by (Scarabaeinae) dung beetles. *Biological Conservation,* 141:1461-1474

Nichols E., Gardner T.A., Peres C.A. and Spector S. (2009). Co-declining mammals and dung beetles: an impending ecological cascade. *Oikos*, 118:481-487

Noss R.F. (1990). Indicators for monitoring biodiversity: a hierarchical approach. *Conservation Biology*, 4:335-364

Numa C., Verdu R.J., Sanchez A. and Galante E. (2009) Effect of landscape structure on the spatial distribution of Mediterranean dung beetle diversity. *Diversity and Distributions*, 15:489-501

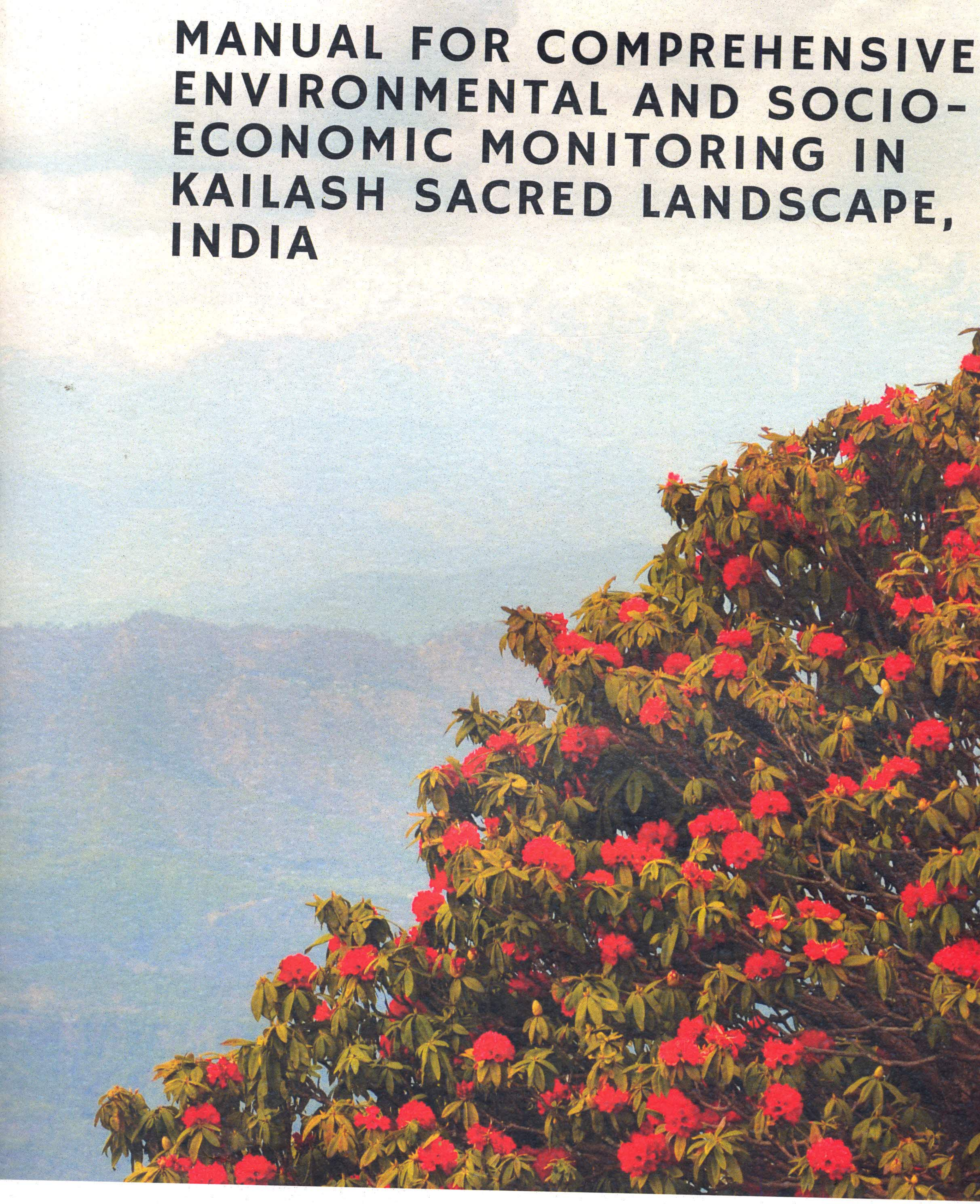
Numa C., Lobo M.J. and Verdu R.J. (2012) Scaling local abundance determinants in mediterranean dung beetles. *Insect Conservation and Diversity*, 5:106-117

Scholtz C.H., Davis A.L.V. and Kryger U. (2009). Evolutionary Biology and Conservation of Dung Beetle. *Pensoft publisher*, 567pp

Shahabuddin Hasanah U. and Elijonnahdi (2014). Effectiveness of dung beetles as bioindicators of environmental changes in land-use gradient in Sulawesi, Indonesia. *Biotropia,* 21(1):48-58

MONA CHAUHAN AND V.P. UNIYAL
Wild Life Institute of India, Chandrabani, Dehradun
E-mail: uniyalvp@wii.gov.in

MANUAL FOR COMPREHENSIVE ENVIRONMENTAL AND SOCIO-ECONOMIC MONITORING IN KAILASH SACRED LANDSCAPE, INDIA



भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Chapter 10. Monitoring insects in pilot sites of Kailash Sacred Landscape – India

V.P. Uniyal and Mona Chauhan*

Wildlife Institute of India, Chandrabani, Dehradun 248001, India
**Email: uniyalvp@wii.gov.in*

10.1 Background

Monitoring is considered as an essential component of any viable strategy to conserve biological diversity because it provides a basis to track the status of various components of biodiversity over time in the context of different management regimes (Common & Norton, 1995). What, where, when and how to monitor are the most pertinent questions in any scheme of monitoring. At least two approaches exist in this regard: (i) firstly, periodical `blind' or `total' data gathering on each and every species or element of habitat those are occurring on a fixed, permanent transect, plot, etc., subsequent data analysis and infer what has happened to species richness, diversity, productivity, succession, etc., and (ii) secondly, based on the preliminary knowledge of the study area, selected taxa are identified as "indicator" or "vital signs" for monitoring. Hilty & Merenlender (2000) have reviewed the criteria for selecting indicator taxa, step-wise process for selection of indicator taxa, and to test the criteria against the indicator taxa that are currently being used to monitor ecosystem health. Invertebrates have been widely proposed and used as indicator taxa for monitoring.

Several groups of insects such as dragon flies, butterflies, moths and bees can be used effectively as indicators of environmental change. This chapter deals with basic tools and techniques for collection of baseline data and subsequent monitoring of

WILDLIFE INSTITUTE OF INDIA

Chandrabani, Dehradun - 248001, India
Tel.: +91 135 2640111 - 115
Fax.: +91 135 2640117
Email.: wii@wii.gov.in
Website.: http://www.wii.gov.in

ISBN No: 81-85496-30-7

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

GBPIHED

Ministry of Environment, Forest & Climate Change

Uttarakhand Space Application Centre

CENTRAL HIMALAYAN ENVIRONMENT ASSOCIATION
CHEA

ICIMOD

Preliminary Assessment of Invertebrate's diversity in Lansdowne Forest Division, Uttarakhand

Mona Chauhan and V.P. Uniyal

Wildlife Institute of India, Chandrabani, Dehradun, 248001 Uttarakhand

(Corresponding author: mona@wii.gov.in)

Abstract

Effects of various negative ecological processes such as climate change, global warming, increased anthropogenic pressure on forest ecosystem can alter the population of ecologically and economically beneficial insects thus it is the primary need to create competent ecological data to address the future challenges like range shift of animals. Insect conservation is fundamental to not only biodiversity conservation, but also to sustainable agriculture and a sustainable biosphere. Primary objective of this study was documentation of baseline ecological information (distribution, abundance status) on insects in Lansdowne forest division of Uttarakhand. Study area has been stratified on the basis of elevation, habitat and vegetation types to explore the insect diversity along each gradient. Standardized methods of insect collection viz; hand sorting, pitfall trapping, light trapping and vegetation beating have been used to collect insects. About 225 morph species, 11 orders and 44 families of invertebrates have been identified so far.

Keywords: Vulnerability, ecosystem, forest management, climate change

1. Introduction

Insects are most diverse and fascinating group of organisms contributing in ecosystems in order to sustain the mankind on earth. Undisputed dominant role of bees in pollination to secure the food security, bio control agent of various diseases causing mediator (water strider, ladybird beetles, dragonflies, spiders, beetles). Pollinators are also important for the reproduction of more than 65% of the world's wild plants (Kearns et al., 1998; Ashman et al., 2004). Globally, they are responsible for pollinating approximately 30,000 plant species (Buchmann and Nabhan, 1996, Wrattena et al., 2012). Soil nematodes, ants and dung beetles enhance soil fertility. Termites are amongst the main macroinvertebrate decomposers in arid and semi-arid environments, and exert additional impacts through the creation of biostructures (mounds, galleries, sheetings, etc.) with different soil physical and chemical properties (Jouquet et al; 2011). Their population is facing immense pressure of numerous ecological detrimental activities like forest degradation, deforestation, global warming and climate change. Lansdowne division is situated in Shivalik and Lesser Himalayan landscapes which is home to rich flora and fauna and is under constant threat of increasing anthropogenic pressure, forest fire, climate change and forest fragmentation. Climate change has many direct and indirect effects on an ecosystem. It is one of the triggering factors for forest fires combined with anthropogenic activities. The major observable impacts of climate change phenomenon are drying up of streams and water sources, increased occurrences of disasters like forest fires, landslides, cloud bursts, erratic rainfall and precipitation pattern, increased temperature etc. These alter the forest ecosystem in many ways. Insects, which are one of the most ecologically important taxa, have also been affected in several ways. The effect of climate change on invertebrates can be long lasting or transitory. However, the invertebrates show enormous variability in response climate change. In a forest ecosystem, the inhabitant invertebrates can broadly be divided into those which remain confined to the litter layers and those which inhabit the habitat temporarily or not at all. The invertebrates which survive have specific adaptations like high mobility, limiting their water usage, resistance to high temperatures etc. which are characteristics for adapting to seasonal variations.

These changes have a large impact on the overall functioning of the Himalayan ecosystem and a scientific study of is needed to address and mitigate the effects of the present and emerging consequences of climate change.

2. Materials and Methods

Study Area: Lansdowne Forest Division (LFD), Uttarakhand

Lansdowne forest division is an important division which connects Rajaiji and Corbett national park. It is located in Pauri Garhwal district in northern Himalayas of Uttarakhand, comprising an area of 5,230 square kilometers (2,020 sq. m). It is situated between 29° 45' to 30°15' North Latitude and 78° 24' to 79° 23' East Longitude. This region is immensely rich with 4000 species of plants, having remarkable diversity in its natural vegetation by virtue of its being at a great range of elevation. In addition to its climatic variations, particularly in temperature and precipitation associated with the alignment and altitudes of ranges and nature of valleys, determine the altitudinal growth and variety of vegetation. The landuse pattern of the area indicates the presence of dense forest covering about one-third of the area and open forest covering about half of the area. Rest of the area is occupied by agriculture, habitation, snow-cover, water bodies and open areas. According to the forest classification of Champion and Seth (1968), following forest types can be recognized in Lansdowne Forest Division

(1) Sub-type 3C/C2a. Moist Shivalik sal forest

(2) Sub-type 5B/Cla. Dry Shivalik sal forest

(3) Sub-type 5B/Clb. Dry plain sal forest

(4) Type 5B/C2. Northern dry mixed deciduous forest

(5) Sub-type 5/E9. Dry bamboo brakes

(6) Sub-type 9/Cla. Lower or Shivalik chir pine forest

This division also harbors great diversity of fauna species like tiger (Panthera tigris tigris), Himalayan black bear (Selenarctos thibetanus), yellow-throated marten (Martes flavigula), leopard cat (Felis bengalensis), leopard (Panthera pardus), wild boar (Sus scrofa), and Indian muntjac.

3. Sampling methods

The present study is confined to five ranges of Lansdowne Forest Division namely Dugudda, Kothri, Kotdwar, Lansdowne and Laldhaang. A total of 25 sampling sites were chosen across the entire forest division with 5 sites in each range. These sites were representatives of the area within the range. Monitoring the abundance of invertebrate populations is increasingly valuable to understand their population dynamics, plan management strategies and assess the attainment of conservation targets. There are many sampling techniques for the collection of invertebrates like handpicking, sweep netting, beating, aerial netting, pitfall trapping and light trapping. All of these techniques have been used to collect invertebrates from different habitat. These sampling techniques have no detrimental impact on longer-term trend of invertebrate population, since no intensive sampling of a highly localized sampling has been made.

4. Results

During the study conducted, about 225 species of invertebrates falling into eleven orders have been identified as: Blattoida (cockroaches and termites), Coleoptera (beetles), Dermaptera (earwigs), Diptera (flies), Hemiptera (bugs and cicada), Hymenoptera (bees and wasps), Lepidoptera (butterfly and moth), Odonata (dragonfly and damselfly), Orthoptera (grasshoppers and crickets), Plecoptera (stonefly) and Araneae (spiders) were recorded (Table1 and 2).

Figure 3: Insects identified from study area

Table 1: Number of invertebrates (insects & spiders) recorded from Lansdowne Forest Division

Invertebrates orders	Number of families	Number of species
Blattoida	02	03 species
Coleoptera	11	58 species
Dermaptera	01	02 species
Diptera	-	07 species
Hemiptera	03	18 species
Hymenoptera	01	12 species
Lepidoptera	14	62species
Odonata	03	11 species
Orthoptera	-	12 species
Plecoptera	-	02 species
Aranae	10	38 species
Total	**44**	**225**

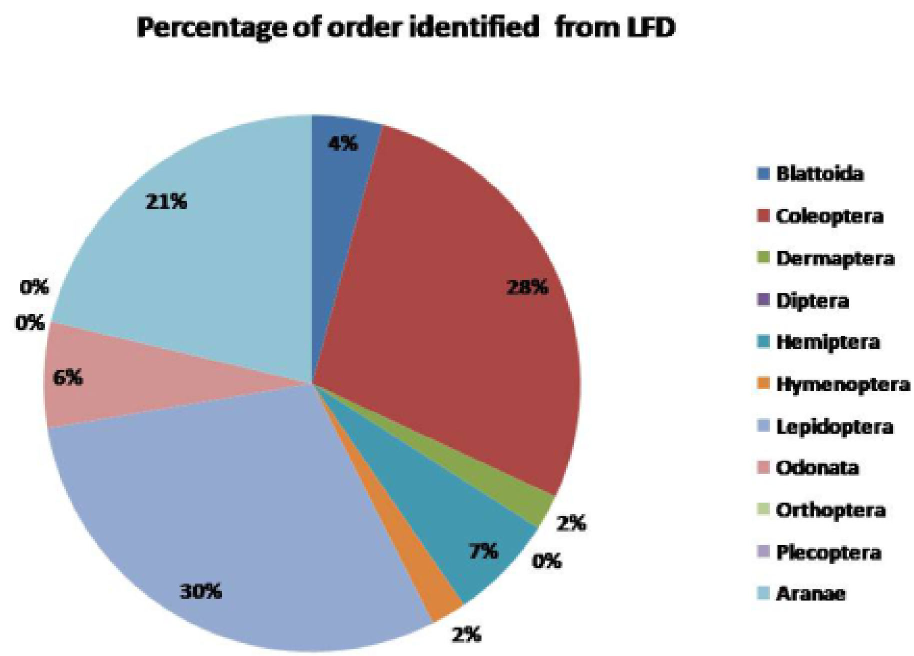


Figure 4: Percentage value of identified species in each order

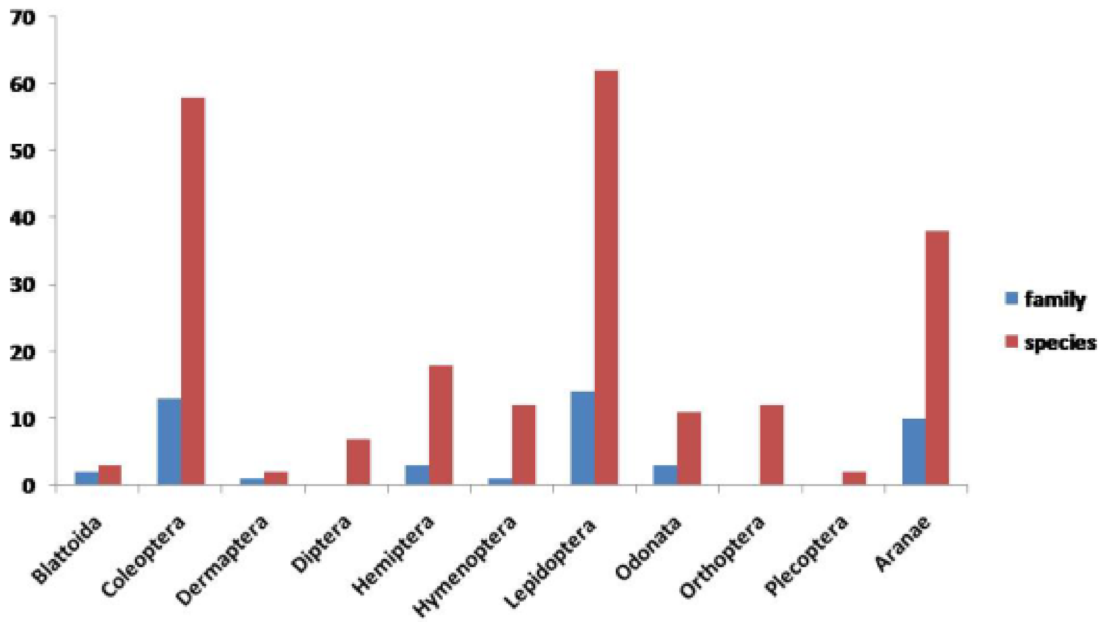


Figure 5: No. of Family and Species identified from LFD

Table 2: Invertebrates recorded from LFD

Invertebrates recorded from LFD, Uttarakhand

Order	Family	Species	Unidentified species
1. Blattoida	Blattidae	*Periplanata amaricana*	
	Ectobiidae	*Blatella germanica*	
	-	Isoptera sp.	01
2. Coleoptera	Carabidae	Carabidae sp.	02
	Cerambycidae	Cerambycidae sp.	03
		Spidimorpha westwoodi	
		Zygogramma bicolorata	
		Chrysomelidae sp.	03
		Spidimorpha sp.	
		Agelastica sp.	
		Chiidopsis bipunctata	
	Coccinellidae	*Coccinella septumpunctata*	
		Henosepilachna sp.	
		Epilachna vigintioctopunctata	

		Coccinellidae sp.	01
	Curculionidae	Curculionidae sp.	02
	Elateridae	Elateridae sp.	02
		Athous sp.	
		Carcinops pumilio	
	Hybosoridae	*Hybosorus orientalis*	
	Hydrophilidae	*Hydrophilus* sp.	
	Scarabaeidae	*Aphodius marginellus*	
		Cetonia bensoni	
		Chiloloba acuta	
		Phyllognathus dionysius	
		Xylotrupes gideon	
		Hybosorus orientalis	
		Holotrichia longipennis	
		Holotrichia problematica	
		Melolontha flabellata	
		Apogonia proxinma	
		Catharsius molosus	
		Euoniticellus pallipes	
		Oniticellus cinctus	
		Onitis philemon	
		Onthophagus dama	
		Sisyphus neglectus	
		Adoretus bimarginatus	
		Anomala dorsalis	
		Anomala rufiventris	
		Anomala varicolor	
		Popillia cyanea	
		Scarabaeidae sp.	06
	Tenebrionidae	Tenebrionidae sp.	03
3. Dermaptera	-	Dermaptera sp.	02
4. Diptera	Syrphidae	Syrphidae sp.	02
	-	Diptera sp.	05
5. Hemiptera	Belostomatidae	Belostomatidae sp.	01
	Pseudococcidae	Sternorrhyncha sp.	01
	Pyrrhocoridae	Pyrrhocoris sp.	01
	-	Hemiptera sp.	15

6. Hymenoptera	-	Andrenidae sp.	01
	Apidae	*Xylocopa aestuans*	
		Apis dorsata	
		Apis indica	
		Bombus haemorrhoidalis	
		Xylocopa latipes	
		Xylocopa sp.	01
	-	Hymenoptera sp.	05
7. Lepidoptera	Hesperiidae	*Spialia galba*	
	Hesperiidae	*Sarangesa dasahara*	
	Lycaenidae	*Heliophorus sena*	
		Zizula hylax	
	Nymphalidae	*Acraea violae*	
		Aglais kaschmirensis	
		Ariadne merione	
		Cyretis thydamas	
		Danaus genutia	
		Junonia lemonias	
		Mycalesis perseus	
		Neptis hylas	
		Phalanta phalantha	
		Vanessa cardui	
	Papilionidae	*Pachliopta aristolochiae*	
		Papilio arcturus arius	
	Pieridae	*Catopsilia pomona*	
		Catopsilia pyranthe	
		Cepora nerissa	
		Pieris brassicae	
		Pieris canidia	
	Arctiidae	*Aglaomorpha plagiata*	
		Aloa lactinea	
		Cyana puella	
		Cretanotos transiens	
		Miltochrista cuneonotatas	
		Nannoarctia obliquifascia	
		Nyctemera adversata	

		Arctiidae sp.	02
	Crambidae	Crambidae sp.	05
	Drepanidae	Drepanidae sp.	01
	Erebidae	Erebidae sp.	05
	Eupterotidae	Eupterotidae sp.	01
	Geometridae	Geometridae sp.	07
	Noctuidae	Noctuidae sp.	07
	Nolidae	*Xanthodes transversa*	
	Sphingidae	*Theretra nessus*	
		Theretra clotho	
		Sphingidae sp.	03
8. Odonata	Libellulidae	*Orthetrum trianulate*	
		Neurothemis tullia	
		Orthetrum sabina	
		Rhyothemis variegata	
		Trithemis pallidinervis	
	-	Odonata sp.	06
9. Orthroptera	-	Orthroptera sp.	12
10. Plecoptera	-	Placoptera sp.	02
	Spiders recorded from LFD		
1. Aranae	Agelinidae	Agelena sp.	
	Araneidae	Araneus sp.	01
		Neoscona sp.	
		Argiope sp.	
	Lycosidae	Pardosa sp.	01
	Oxyopidae	Oxyopes sp.	01
	Philodromidae	Philodromus sp.	
	Salticidae	Pseudcius sp.	01
		Plexippus paykulli	
	Sparassidae	*Heteropoda venatoria*	
	Sparassidae	Olios sp.	
		Pseudopoda sp.	
	Thomisidae	Misumena sp.	
	Uloboridae	Ulborus sp.	
	Thomisidae	Xysticus sp.	
	-	Aranae sp.	23

This forest division shows great diversity of invertebrates due to the different type of habitat from teak forest, mixed forest, pine forest and also the vegetation regeneration, and excellent ground cover with leaf liters which is a necessity in order to provide potential reproductive breeding habitats for invertebrates. About 225 morph species, 11 orders and 44 families of invertebrates have been identified so far.

5. References

Ashman, T.L., Knight, T.M., Steets, J.A., Amarasekare, P., Burd, M., Campbell, D.R., Dudash, M.R., Johnston, M.O., Mazer, S.J., Mitchell, R.J., Morgan, M.T. and Wilson, W.G. 2004. Pollen limitation of plant reproduction: ecological and evolutionary causes and consequences. Ecology. 85: 2408-2421.

Buchmann, S.L. and Nabhan, G.P. 1996. The Forgotten Pollinators. Island Press, Washington, DC, USA.

Kearns, C.A., Inouye, D.W. and Waser, N.M. 1998. Endangered mutualisms: the conservation of plant–pollinator interactions. Annual Review of Ecology, Evolution, and Systematics. 29: 83-112.

Jouquet, P., Traoré, S., Choosai, C.,Hartmann, C. and Bignell, D. 2011. Influence of termites on ecosystem functioning. Ecosystem services provided by termites. European Journal of Soil Biology. 47: 215-222.

Wrattena, D.S., Gillespie, M., Decourtyec, A., Maderd, E. and Desneuxf, N. 2012. Pollinator habitat enhancement: Benefits to other ecosystem services. Agriculture, Ecosystems and Environment. 159: 112-122.