TAXONOMY AND ECOLOGY OF DUNG BEETLES (COLEOPTERA: SCARABAEIDAE: SCARABAEINAE) IN A THORNY FOREST IN THE SOUTH WESTERN GHATS

Thesis submitted to the University of Calicut
in partial fulfilment of the requirements for the award of the degree of
Doctor of Philosophy in Zoology

By

Sobhana K. A.

Under the guidance of

Dr. Benny T. M.

P.G. & RESEARCH DEPARTMENT OF ZOOLOGY
ST. JOSEPH'S COLLEGE, DEVAGIRI
KOZHIKODE- 673008, KERALA

2014

P.G. & RESEARCH DEPARTMENT OF ZOOLOGY
ST. JOSEPH'S COLLEGE, DEVAGIRI
KOZHIKODE - 673 008, KERALA
INDIA

Dr. Benny T. M.
Associate Professor
☎ 91- 495-2352145 (O), 91-9447609327 (M)

CERTIFICATE

Certified that the thesis entitled "**Taxonomy and ecology of dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae) in a Thorny forest in the south Western Ghats**" submitted by **Mrs. Sobhana K. A.** to the University of Calicut for the award of the degree of Doctor of Philosophy in Zoology, is a bonafide record of research work done by her in this department under my guidance and supervision. This has not previously formed the basis for any award of degree or diploma.

Mrs. Sobhana K. A. has succesfully completed the preliminary qualifying examination prescribed by the University of Calicut.

Place : Devagiri
Date : 28-11-2014

Benny T. M.

P.G. & RESEARCH DEPARTMENT OF ZOOLOGY
ST. JOSEPH'S COLLEGE, DEVAGIRI
KOZHIKODE - 673 008, KERALA
INDIA

Dr. Benny T. M.
Associate Professor

☎ 91- 495-2352145 (O), 91-9447609327 (M)

CERTIFICATE

Certified that the publication titled "Sobhana K.A., Sabu K.T. & Benny T.M. 2013. Checklist of dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae) associated with a dry deciduous forest in the south Western Ghats. *Hexapoda,* 20(1&2): 94-97" is a publication of **Mrs. Sobhana K. A.** in a peer reviewed journal.

Place : Devagiri
Date : 28-11-2014

Benny T. M.

DECLARATION

I do hereby declare that the thesis entitled "**Taxonomy and ecology of dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae) in a thorny forest in the south Western Ghats**" submitted to the University of Calicut for the award of the Degree of Doctor of Philosophy in Zoology has not been submitted for the award of any other degree or diploma and represents the original work done by me.

Place : Devagiri
Date : 28-11-2014

Sobhana K. A.

ACKNOWLEDGEMENTS

With immense pleasure I record my profound sense of gratitude to my guide and supervisor **Dr. Benny T.M.**, Associate Professor, P.G. and Research Dept. of Zoology, St. Joseph's College, Devagiri, Calicut for introducing me to the fascinating world of beetles. I am extremely thankful for his tireless mentoring, guidance, inspiration and constant encouragement throughout the course of this study.

I would like to express my sincere gratitude to **Dr. Sabu K. Thomas**, Associate Professor, P.G. and Research Dept. of Zoology, St. Joseph's College, Devagiri for his patience, motivation, enthusiasm, and immense knowledge throughout my thesis work. His guidance helped me in all the time of research and writing of this thesis.

I wish to acknowledge the help provided by **E-grantz**, Kerala state SC Development Board for providing the funding which allowed me to undertake this research.

I am grateful to **Fr. Benny Sebastian**, Principal, St. Joseph's College, Devagiri for providing all the necessary facilities during the course of my work. I would like to offer my special thanks to **Dr. A.T. Thomas**, former Head, P.G. and Research Dept. of Zoology, St. Joseph's College, Devagiri for providing the facilities throughout my research work and also for his support, understanding and encouragement.

I wish to express my sincere thanks to **Dr. George Mathew**, Head of the Department, P.G. and Research Dept. of Zoology, St. Joseph's College, Devagiri and to all the teaching and non teaching staffs of the P.G. and Research Dept. of Zoology, St. Joseph's College, Devagiri for all the help rendered during the course of my research.

I am grateful to the **Chief Wild life Warden**, Kerala, for providing all the necessary facilities during the course of my work.

I am extremely thankful to my friends **Dr. Vinod K.V., Dr. Shiju T. Raj**, **Dr. Latha Mathews**, **Dr. Nithya Santhiandran**, **Mrs. Simi Venugopal**, **Dr. Arunraj C.**, **Mr. Nirdev P.M.**, **Mrs. Ajitha K.V.**, **Ms. Aswathi P.** and **Mrs. Seena C.M.** who were of tremendous help to me throughout the course of my research.

I am also thankful to all the teaching and non-teaching staff of the P.G. and Research Dept. of Zoology, St. Joseph's College, Devagiri for their valuable co-operation and help.

I am extremely thankful to **Mr. Rineesh and family** to provide facility to stay in their house as a paying guest during my study period and my room mates **Ms. Salva Hassan, Ms. Hanan Hameed, Dr. Krishnapriya, Ms. Silpa P.S.**, etc.

I am deeply indebted to my family especially to my brother **Mr. N. Sukumaran** and my husband **Mr. Sineesh K.B.** for their wholehearted support, cooperation, encouragement and prayers which formed the basis of my research work.

Above all I thank God for blessing me with health and confidence to carry out the work successfully.

Sobhana K. A.

CONTENTS

Chapter 1

INTRODUCTION

Dung beetles: The family Scarabaeidae (Insecta: Coleoptera) generally known as dung beetles are detritivorous insects which consume mainly mammalian dung although some may eat dung from other animals and even distinct resources as decomposing animals, fungi and rotten fruits (Halffter & Mathews 1966). The name 'scarab' comes from the Greek work '*karabos*' meaning a horned beetle or a stag beetle. Their feeding behaviour is important for the ecosystem by improving the quality of soil (nutrient cycling, improving aeration and water permeability), increased plant nutrient uptake and yield (Miranda *et al*. 1998), control of pest flies and enteric parasites of vertebrates (Bergstrom *et al*. 1976) and secondary seed disposal of seed defecated by fungivorous vertebrates (Estrada & Coates-Estrada 1991; Feer 1999; Andresen 2001, 2002; Andresen & Levey 2004). Dung beetles are distributed in all continents except in Antarctica and are restricted to areas characterized by yearly rainfall of 250 mm or more, a minimum average annual temperature of 15^0 C and within 45^0 latitudinal limits (Halffter 1991). Aside from their functional importance in ecosystems, dung beetles have been proposed as a useful indicator group of habitat disturbance due to their fast response to environment modifications (Halffter & Favila 1993; Favila & Halffter 1997; Davis *et al.* 2001).

As other beetle families, dung beetles also exhibit a various number of morphological adaptations, both in larval and adult stages in relation with their feeding behaviour. Elongated and bowed legs for handling spherical dung masses and burrowing into the ground. Head with rather broad and flat clypeus, suitable for shovelling materials with which the insects have to deal. This is accompanied by the great development of the metasternum; carrying the hind legs also far back (Arrow 1931; Balthasar 1963a). A considerable mass of dung can thus be held between the legs and compressed into globular shape. The longitudinal position of the middle coxae seems to enable the middle tibiae to exert pressure in the opposite direction to that of the hinder pair, so maintaining a grip of the sphere and leaving the front legs free for its manipulation. The elongated metasternum entails a corresponding shortening of the abdomen even in long tailed forms (Arrow 1931). The extraordinarily long and coiled intestine of the adult when compared to the larva is an adaptation to this special type of microphagous coprophagy (Halffter & Mathews 1966). The adult dung beetles have specialized mouthparts for feeding (Halffter & Mathews 1966). Beetle collect the dung by licking movement of the hairy, pad like maxillary galae and squeeze liquid out of the collected materials between the mandibular molars. The mandibles and maxillae are equipped with fine fringes for manipulating and filtering the semi-liquid constituents of dung. The mandibles also have a large molar area for grinding food particles in the liquid suspension (Halffter & Edmonds 1982; Holter 2000). The liquid with its content of minute particles, run into the pharynx through narrow filtration channels. The furrows are connected to the surface through narrow fissures. Other components of dung are rejected (Madle 1934).

Dung beetles have four stages of development in their lifecycle namely; egg, larvae, pupae and adult. Among the dung beetles there is a range of cooperative behaviour exists between sexes, where female conducts all nesting activity, where male takes part in nest provision and brood care (Halffter & Mathews 1966; Hanski & Cambefort 1991a; Scheffler 2002). Juvenile development take place between 30-50 days from egg to adult and in adverse condition over an year. After emergence from the nest adults undergo a prolonged period of feeding for three to four months for the full development of gonads and eggs. They have an average life span of 60 days to three years (Scheffler 2002).

1.1. Taxonomy of dung beetles

Scarabaeidae is the largest family of insects which contains approximately 7,000 species. Among these subfamily Scarabaeinae are the true dung beetles, which are predominantly coprophagous (faeces eating) (Halffter & Mathews 1966; Scheffler 2002). Scarabaeinae contains approximately 200 genera with more than 3,000 species in the world (Halffter 1991; Krajcik 2006). Scarabaeinae ranges in size from 2–60 mm. Some species are brightly coloured and many have horns or conspicuous protuberances on the head or thorax (Ratcliffe 1991). Scarabaeinae differ markedly from other Scarab subfamilies including Aphodiinae in the very peculiar position of the middle pair of legs which are very widely separated. They also differ from other scarab subfamilies in the placement of the spiracles in the membrane separating the dorsal and ventral plates of the abdomen (and not hidden by the elytra), 8–9 segmented antenna and posterior tibia with a single apical spur (except for *Melocanthon* which has two) (Ratcliffe 1991).

Dung beetles are one of the best studied groups of beetles in terms of taxonomy. The major contributors being Arrow 1931; Janssens 1949; Balthasar 1963a, b; Lawrence & Newton 1995 and Martin-Piera 2000. However, there is still a lack of agreement regarding the taxonomic status of Scarabaeinae. Arrow (1931) placed dung beetles under subfamily Coprinae which he treated as a synonym for subfamily Scarabaeinae and divided it into four divisions (=tribes) namely; Sisyphini, Gymnopleurini, Coprini and Panelini. Janssens (1949) subdivided the group into six tribes: Coprini (including Dichotomiina, Phanaeina and Ennearabdina), Eurysternini, Oniticellini, Onitini, Onthophagini and Scarabaeini (including Eucraniina, Canthoniina, Gymnopleurina, Scarabaeina and Sisyphina). Balthasar (1963a, b) ranked the group as a family comprising two behaviourally distinct subfamilies: Coprinae and Scarabaeinae The former subfamily included the tribes Coprini, Dichotomini, Phanaeini, Oniticellini, Onitini and Onthophagini whereas the latter subfamily included the tribes Eucraniini, Eurysternini, Canthonini, Gymnopleurini, Scarabaeini and Sisyphini. Compared with the classification of Janssens (1949) followed by Halffter & Edmonds (1982), Balthasar's classification had the advantage of the family being divided into two equivalent taxa, which correspond to the biological groups of rollers (subfamily Scarabaeinae) and tunnelers (subfamily Coprinae). Many works (Ferreira 1972; Baraud 1985, 1992; Davis 1993a, b, c, 1994a, b, c, d, 1995, 1996a, b, c, d, 1997; Davis & Dewhurst 1993) followed the precedent set by Balthasar (1963a, b) and is largely supported by the phylogeny of Zunino (1983) which was based on relatively few aedeagal characters and showed a basal split with one lineage composed of tribes primarily with tunnelling habits and the other dominated by ball-rolling tribes. Lawrence & Newton (1995) classified dung beetles into 12 tribes which included Coprini, Dichotomini, Phanaeini, Oniticellini, Onitini, Onthophagini, Eucraniini, Eurysternini, Canthonini, Gymnopleurini, Scarabaeini and Sisyphini and included them in the subfamily Scarabaeinae with which he considered the Coprinae synonymous. New phylogenic studies based on 200 internal and external morphological characters support this classification (Philips *et al*. 2004) and indicate that the subdivision of dung beetles into two subfamilies-Scarabaeinae and Coprinae (Balthasar 1963a, b) is not supportable as ball-rolling taxa are polyphyletic. The classification system of Lawrence & Newton (1995) is being widely followed in recent taxonomic and ecological works (Davis *et al*. 2002; Scheffler 2002, 2005; Arellano & Halffter 2003; Vinod 2009; Sabu *et al*. 2011a). In the present study is also followed the classification system of Lawrence & Newton (1995).

Composition and dynamics of several dung beetle communities in rain forest habitats have been studied in detail (Peck & Forsyth 1982; Nummelin & Hanski 1989; Halffter *et al.* 1992; Davis *et al.* 2000; Escobar 2000; Feer 2000; Arellano & Halffter 2003) and also from the wet forests in Western Ghats (Sabu & Vinod 2005; Anu 2006; Sabu *et al*. 2006, 2007; Vinod & Sabu 2007; Vinod 2009; Latha *et al*. 2011). Tropical dry forests represent a large proportion of the world's terrestrial ecosystems (Bullock *et al*. 1995) and one of the most endangered (Janzen 1988) mostly due to conversion to pasture and agriculture (Burgos & Maass 2004). Mammalian biomass tends to be higher in dry forests than in rain forests, especially in Asian and African dry forests. Many of these species display extraordinary adaptations to the difficult climate. This biome is alternately known as the tropical bane forest biome or the tropical and subtropical deciduous forest biome. Locally some of these forests are also called monsoon forests, and they tend to merge into savannas (Wikramanayake *et al.* 1999). However very little is known about the composition and dynamics of dung beetle communities in tropical dry forests except from Neotropical region (Janzen 1983; Kohlmann & Śanchez-CoÍon 1984; Escobar 1997; Halffter & Arellano 2002). Thus, the assessment of the effects of disturbances in a group of insects that plays an important role in many ecosystem functions and services ought to be a priority in dry forest landscapes. Furthermore, the identification of certain species that could be used in practical conservation programs for monitoring site changes, may be particularly helpful in the endangered dry forests.

The main dry deciduous forests at global level are:- Madagascar dry forests, Nusu and Tenggara dry forests (Indonesia), New Caledonia dry forests (France), Mexican dry forests, Tumbesian-Andean Valleys dry forests (Colombia, Ecuador and Peru), Chiquitano dry forests (Bolivia and Brazil), Atlantic dry forests (Brazil), Hawaii's dry forests and Central Andean dry puna (Argentina, Bolivia, Chile and Peru), Southeastern Indochina dry-evergreen forests and Sri Lanka dry zone dry- evergreen forests (Wikramanayake *et al.* 1999).

In India, dry forests are widely distributed and the main dry forests in Indian mainland are: Chota-Nagpur dry forests, Meghalaya dry forests, Central Deccan Plateau dry deciduous forests, East Deccan dry-evergreen forests, South Deccan Plateau dry deciduous forests and the dry deciduous forests that occur on the eastern slopes of the Western Ghats mountain ranges (Wikramanayake *et al*. 1999). Dry deciduous forests in south Western Ghats are confined to northern slope of Anamalai in Chinnar Wild life Sanctuary, eastern part of Mannarkad Division and South Wayanad Wildlife Sanctuary (Kerala Forests and Wildlife Department 2004).

Vegetation structure is the main factor determining the organization of dung beetle communities (Hanski & Cambefort 1991a; Halffter & Arellano 2002). Studies of the dung beetles in the Neotropical dry forests clearly showed drastic changes in the community composition from the wet season to dry season, with strong reduction in the number of species and their abundance in latter one (Andresen 2005; Hernández 2007; Neves *et al.* 2010; Liberal *et al.* 2011). The seasonality of rainfall is an important factor in communities of dry forest (Murphy & Lugo 1986) and as dung beetle activity is often synchronized or maximized with rainfall in tropical regions (Hanski & Cambefort 1991a), and in tropical forests the degree of such changes increases as the degree of seasonality increases (Peck & Forsyth 1982; Janzen 1983; Feer 2000). The dung beetle community is also directly influenced by high insolation and temperatures factors to which they had to adapt during the invasion of arid areas (Halffter & Mathews 1966) and most dung beetles cannot tolerate these conditions.

No studies have analysed the taxonomy of dung beetles in the dry forests of Western Ghats. Hence an analysis of the taxonomic composition of dung beetles in the thorny forests in Chinnar in the Western Ghats is provided, following the classification system of Löbl & Smetana (2006). These findings would provide new scientific information on the taxonomy of dung beetles from the dry forests in the South Western Ghats.

1.2. Ecology of dung beetles

1.2.1. Functional guild composition

Both larval and adult stages of dung beetles use dung produced by vertebrates particularly large herbivorous mammals (elephant and gaur in forests; cow and sheep in agricultural habitats) and occasionally that of birds and reptiles as food and as substrate for oviposition (Halffter & Mathews 1966; Howden & Young 1981; Young 1981). Among these dung beetles Scarabaeinae use excrement of large mammals, especially like Bovidae and man (Halffter & Mathews 1966). Dung beetles are divided broadly into three functional groups based on their nesting strategies, feeding and breeding *viz.,* rollers (telecoprid nesters), tunnelers (paracoprid nesters) and dwellers (endocoprid nesters) (Cambefort & Hanski 1991).

The dwellers eat their way through the dung and most species deposit their eggs in dung pats without constructing any kind of nest or chamber.

Tunnelers dig a more or less vertical tunnel below the dung pat and transport dung into the bottom of the burrow, this resource may be used either for adult feeding or breeding. Rollers make balls of dung, a transportable resource unit, rolls it for a shorter or longer distance before burying it at a suitable spot. Some adult tunnelers and rollers feed directly in dung pats, but many others feed on their relocated dung reserves (Cambefort & Hanski 1991).

This functional stratification allows dung beetles to minimize the intense competition for limited food and space and also to protect the food from adverse environmental conditions such as heat and excessive dryness (Halffter & Edmonds 1982; Cambefort & Hanski 1991; Scheffler 2002). In Scarabaeinae, dung rolling is associated with tribes Scarabaeini, Gymnopleurini, Sisyphini and Canthonini, dwelling with tribe Oniticellini and tunneling with tribes Coprini, Onitini and Onthophagini (Hanski & Cambefort 1991a).

1.2.2. Temporal guild composition

Diel periodicity of dung beetle species studies mainly distinguish into two major groups, nocturnal and diurnal. It is a wide spread mechanism to avoid competition between closely related species or phylogenetically distant groups. Diel periodicity varies in different habitats and also influenced by vegetation cover, physical parameters, habitat modification and trophic resource availability (Fincher *et al*. 1971; Walter 1985; Gill 1991; Davis 1999; Krell-Westerwalbesloh *et al*. 2004; Feer & Pincebourde 2005). When a resource is an unpredictable, ephemeral patch, it is crucial for the success of any potential user to be in the right place at the right time. This is the more so if the ephemeral nature of the resource is caused by the users themselves, as in rapid degradative successions (Begon *et al*. 1996).

1.2.3. Species diversity

Dung beetles are recognized as a useful taxon for describing and monitoring spatial and temporal patterns of biodiversity (Favila & Halffter 1997; Spector & Forsyth 1998; Davis *et al.* 2001). Species diversity of a landscape includes, the richness of species in the individual communities that make up the landscape (alpha diversity) and the degree of difference between those communities (beta diversity) (Arellano & Halffter 2003).

The parameters affecting the pattern in species richness of dung beetles are an increase in species number with decreasing latitudes and decrease in species richness with increasing altitude (Hanski & Cambefort 1991a) and also the habitat heterogeneity at a regional scale (Schoener 1974; Huston 1994; Rosenzweig 1995; Begon *et al.* 1996). Three aspects of mammalian species richness have direct consequences for dung beetles, the general abundance of mammals determines the level of availability of resources for dung beetles; range of different kinds of mammals determines the range of dung types available; and the size of mammals is important to large species of dung beetles which are dependent on large droppings for breeding (Hanski & Cambefort 1991a).

1.2.4. Indicators of habitat modification

Dung beetles play as an important biological indicator in the ecosystem. A biological indicator is a species or group of species that readily reflects the abiotic or biotic state of an environment represents the impact of environmental change on a habitat, community or ecosystem (McGeoch 1998), biological indicators are used to analyse the effect of human activity on biodiversity (Noss 1990; Pearson & Cassola 1992; McGeoch & Chown 1998).

Dung beetles reflect structural differences between habitats caused by forest type or human habitat modification (Klein 1989; Nummelin & Hanski 1989; Hill 1996; Davis & Sutton 1998; Davis *et al*. 2001). The potential of dung beetles as indicators for disturbance has been reviewed by Halffter & Favila (1993) and McGeoch *et al*. (2002).

Dung beetles have been proposed as a good biological indicators of disturbance by human activity in tropical terrestrial environments because they are very sensitive to changes in microclimatic variables, vegetation structure, soil characteristics and abundance of food resources in the habitats they live (Nealis 1977; Halffter *et al.* 1992; Lumaret *et al.* 1992; Osberg *et al.* 1994; Davis 1996a; Lumaret & Iborra 1996; Estrada *et al.* 1999; Escobar 2000). Selection of indicator species for habitats helps in monitoring the habitats for changes in the future.

1.2.5. Seasonality

The majority of dung beetle species exhibit environmentally induced seasonality and is active during favourable periods. Seasonality in the occurrence of dung beetles is more in more seasonal environments (Cambefort 1984; Hanski 1989; Morelli *et al*. 2002; Andresen 2005) and no seasonality was observed in less seasonal environments (Peck & Forsyth 1982; Hanski 1989). Some species of dung beetles exhibit highly seasonal patterns of nesting and adult activity as a response to either the environment or to competition (Janzen 1983; Scheffler 2002). Seasonality in insects is generally controlled by three factors: resource availability, temperature and rainfall (Wolda 1988). Seasonal fluctuation in food availability is recognized as a common correlate of tropical insect seasonality but difficult to tease out of the morass of other environmental parameters that change with the alternation of the wet and dry seasons. Some species of dung beetles exhibit highly seasonal patterns of nesting and adult activity as a response to either the environment or to competition (Janzen 1983; Scheffler 2002).

Dung beetle activity varies seasonally with high numbers recorded in the warm, rainy season and low numbers in the cool, dry season (Davis 1996a). In areas with pronounced wet and dry periods, insects tend to be seasonal in their activity (Wolda 1978). In most species of dung beetles, the adults show increased activity during the rainy season (Wolda & Estribi 1985; Edwards 1988; Cambefort 1991; Doube 1991; Hanski & Cambefort 1991a; Lumaret & Kirk 1991; Rougon & Rougon 1991). However, seasonal activity is less pronounced in areas without a severe dry season (Peck & Forsyth 1982; Waage & Best 1985; Wolda & Estribi 1985; Berytenbach & Berytenbach 1986; Hanski & Krikken 1991) although it does still occur (Morón *et al.* 1986).

Seasonality in the occurrence of dung beetles is more in more seasonal environments (Cambefort 1984; Hanski 1989; Morelli *et al*. 2002; Andresen 2005) and no seasonality was observed in less seasonal environments (Peck & Forsyth 1982; Hanski 1989). So the studies on seasonality help in determining how the various environmental factors that vary with seasons affect the dung beetle assemblages.

1.3. Significance of the study

In worldwide, the composition and dynamics of several dung beetle communities in rainforest habitats have been studied in detail and also in the tropical wet forests in Western Ghats. Tropical dry forests represent a large proportion of the world's terrestrial ecosystems (Bullock *et al*. 1995) and one of the most endangered (Janzen 1988), mostly due to conversion to pasture and agriculture (Burgos & Maass 2004). However, very little is known about the composition and dynamics of dung beetle communities in tropical dry forests. Dung beetle ecology and community structure from the tropical dry ecoregions of India in general and the Western Ghats in specific, have not received enough attention. No studies exist on the effect of vegetation types on the community structure of dung beetles from the region.

High levels of biodiversity, endemism and unusual biogeographic patterns has lead to recognition of the Western Ghats as one among the 34 global hotspots of biodiversity (Myers 2003; Bossuyt *et al*. 2004; Mittermeier *et al*. 2004). The Western Ghats is the only tropical forest ecoregion of the Indian peninsula and is well known for regional variation in vegetation, rainfall patterns, topography and high levels of endemism across its entire stretch (Nair 1991).

Nearly three-fourths of the natural vegetation in the ecoregion has been cleared or converted and the remaining severely fragmented forests are one of the major conservation priorities on a global scale due to their fragility, biological richness, high rates of endemism and multiple anthropogenic threats (Pascal 1991). Some of the major conservation issues facing the South Western Ghats landscape region are human wildlife conflict, timber smuggling and poaching of wild life (Commercial), unregulated tourism, improperly planned infrastructure development, forest encroachment (illegal), forest conversion (legal), unsustainable extraction/ use of forest products for subsistence and for commercial use, invasive alien species and forest fires (WWF 2008). As the extent of natural habitat shrinks, the future of biodiversity depends increasingly on the conservation potential of existing forests and remnants of native habitat embedded in landscapes devoted primarily to human activities. Ecosystem disruption through human activity poses a major threat to the long term prospects of biodiversity conservation (Whitemore & Sayer 1992).

The structure of the vegetation is the main factor determining the organization of dung beetle communities (Peck & Forsyth 1982; Janzen 1983; Feer 2000) cataloguing the dung beetle fauna from the forest would serve to recognize the effect of dung beetle community structure across different vegetational types and will add to the general efforts towards the conservation of biodiversity in Western Ghats. With the current state of lack of knowledge of the composition and structure of a dung beetle community as well as the effect of vegetation on dung beetles from this region, the findings from this study certainly would provide new scientific information on dung beetles from Western Ghats.

Present study, therefore, aimed to analyse the diversity, guild structure and seasonality of the dung beetle community in the dry forest of the Chinnar region in the south Western Ghats.

1.4. Objectives

1. Taxonomic studies of dung beetles in the Thorny forest of Chinnar and preparation of check list and a workable key for identification of dung beetle fauna in South Western Ghats.
2. Community diversity across the habitat.
3. Guild structure, diel periodicity, abundance and seasonality studies.

Chapter 2

REVIEW OF LITERATURE

2.1. Taxonomy of dung beetles

2.1.1. Taxonomy of dung beetles of the world

Taxonomy of dung beetles is fairly well studied and listed below are the important highlights of the major taxonomic works. The dung beetles now classified under subfamily Scarabaeinae and members of the suborder Lamellicornia were included by Linnaéus (1758) under a single genus, the *Scarabaeus.* Fourcroy (1785) separated the dung beetles from the Linnean *Scarabaeus* and constituted a new genus *Copris*. Latreille (1796) separated the species with 11-jointed antennae under the name *Geotrupes*. Illiger (1798) introduced two new genera *Oryctes* and *Aphodius* Fabricius (1798) separated genus *Onitis* from genus *Copris.* Creutzer (1799) proposed the name *Actinophorus* for the ball rolling beetles now included in the genera *Scarabaeus* and *Gymnopleurus*.

The name *Ateuchus* for *Scarabaeus sacer* and its congeners introduced by Weber (1801). Latreille (1802) introduced the largest dung beetle genus, *Onthophagus.* The genus *Gymnopleurus* was established by Illiger (1803). Latreille (1807) introduced the genus *Sisyphus.* Serville in 1825 introduced the genus *Oniticellus*. *Drepanocerus* was introduced by Kirby (1828). Hope (1837) introduced two new genera, *Catharsius* and *Heliocopris* comprising large dung beetles. Thomson (1863) established the genus *Caccobius*. The genus *Liatongus* was introduced by Reitter (1892) and *Tiniocellus* by Péringuey (1900). Boucomont (1914) established the genus *Phacosoma.* Due to homonymy, Vaz-de-Mello (2003) renamed the genus *Phacosoma* as

Ochicanthon. The genus *Tibiodrepanus* was described by Krikken (2009) which is previously assigned to the genus *Drepanocerus* Kirby 1828. Discarding the classification system proposed by Lacordaire (1856), Arrow (1931) placed dung beetles in four divisions (=tribes) namely; Scarabaeini, Sisyphini, Coprini and Panelini under the subfamily Coprinae with which he considered the Scarabaeinae synonymous. Janssens (1949) subdivided Scarabaeinae into six tribes: Coprini, Eurysternini, Oniticellini, Onitini, Onthophagini and Scarabaeini. Balthasar (1959) described *Digitonthophagus* as a subgenus of *Onthophagus* Latreille.

Later, Balthasar (1963a, b) ranked the dung beetles as a family comprising two behaviourally distinct subfamilies: Coprinae and Scarabaeinae. Subfamily Coprinae included the tribes Coprini, Dichotomini, Phanaeini, Oniticellini, Onitini, and Onthophagini and the subfamily Scarabaeinae included the tribes Eucraniini, Eurysternini, Canthonini, Gymnopleurini, Scarabaeini and Sisyphini. Compared with the classification of Janssens (1949), Balthasar's classification had the advantage as the family is divided into two equivalent taxa, which correspond to the biological groups of rollers (subfamily Scarabaeinae) and tunnelers (subfamily Coprinae).

Zunino (1981) raised *Digitonthophagus* to genus level. Phylogeny of Zunino (1983) based on relatively few aedeagal characters, showed a basal split with one lineage comprising tribes primarily with tunneling habits and the other dominated by ball-rolling tribes, supporting Balthasar's system of classification. New genus *Cleptocaccobius* introduced by Cambefort (1984) was added to the tribe Onthophagini. The comparative analysis of the male and female genitalia of subfamily Scarabaeinae, disputed the monophyly of the tribes Onitini, Coprini and Dichotomini (Zunino 1984). Cambefort (1985) provided the revision of the oriental species of *Cleptocaccobius* and four new species *C. arrowi*, *C. khatimae*, *C. durantoni* and *C. boucomonti* together with a new subspecies *C. simplex meridionalis* were added. Larval and adult characters were used to study the phylogenetic relationships within the most speciose tribe Onthophagini (Zunino 1979; Martin-Piera & Zunino 1983, 1986; Palestrini 1985; Martin-Piera 1986, 2000; Lumaret & Kim 1989).

Lawrence & Newton (1995) placed all 12 tribes in the subfamily Scarabaeinae with which they considered the Coprinae synonymous. Browne & Scholtz (1995, 1998) studied the phylogeny of Scarabaeidae based on the characters and evolution of hind wing articulation and wing base. Montreuil (1998) confirmed the monophyly of Coprini and Dichotomini. Recent and complete phylogeny of the Onthophagini was based on 12 external and internal morphological traits (Martin-Piera 2000).

New phylogenic studies of Philips *et al*. (2004) based on 200 internal and external morphological characters support this classification. Krikken (2009) revised and discussed the taxonomic and biogeographic status of genus *Drepanocerus* Kirby and the related genera and split the genus into five new subgenera namely; *Afrodrepanus, Clypeodrepanus, Latodrepanus, Sulcodrepanus* and *Tibiodrepanus*.

Regional lists of dung beetles are available from South Africa (Péringuey 1900), African Tropical region (Gillet 1908, 1911), Sumatra (Gillet 1924), China (Gillet 1935; Nakane & Shirahata 1957), Southwest Arabia (Paulian 1938), Mexico, Central America, the West Indies and South America (Blackwelder 1944), Afganistan (Balthasar 1955), Japan (Nakane & Tsukamoto 1956), Florida (Woodruff 1973), Panama and Costa Rica (Howden & Young 1981; Howden & Gill 1987; González-Maya & Mata-Lorenzen 2008), Nebraska (Ratcliffe 1991), Europe (Baraud 1992), Colombia (Lopera 1996), Nearctic Realm (Smith 2003) and Palaearctic region (Löbl & Smetana 2006). Check list of dung beetles of the world were prepared by Krajcik (2006) and Schoolmeesters (2011). Siddiqui *et al*. (2014) provided an annotated list of scarabs collected in all possible localities of Pakistan with the faunal composition of scarabs occurring in Pakistan.

2.1.2. Taxonomy of dung beetles of the Indian region

The first comprehensive account of Scarabaeid beetles of the Indian subcontinent was published by Arrow (1931), in which he reported four divisions, 26 genera and 354 species. An addition to the knowledge on Indian dung beetles was given only after three decades by Balthasar (1963a, b) in his monograph on Scarabaeidae and Aphodiidae in the Palearctic and Oriental region. Subsequent to the efforts of Arrow (1931) and Balthasar (1963a, b) taxonomic studies on dung beetles were limited to the occasional catalogues and regional check lists published by Zoological Survey of India from different regions.

Biswas (1978a, b) described four new species namely; *Onthophagus* (*Strandius*) *subansiriensis, Copris siangensis*, *Onitis assamensis* and *Drepanocerus kazirangensis* from Arunachal Pradesh and Assam. Biswas & Chatterjee (1985) reported seven new species from Namdapha Wildlife Sanctuary namely; *Oniticellus namdaphensis*, *O. subhendui*, *O. gayeni*, *Onthophagus tirapensis*, *O. arunachalensis*, *O. songsokensis* and *O. royi.* Newton & Malcolm (1985) recorded 22 species from the Kanha Tiger Reserve. Sewak (1985) reported eight species from Gujarat. Male genitalia of three Indian genera namely; *Catharsius* (Sewak 1985), *Onthophagus* (Sewak 1986) and *Oniticellus* (Sewak 1988) and taxonomic importance were studied.

Sewak & Yadva (1991) collected 36 species from Western Uttar Pradesh. Veenakumari & Veeresh (1996) recorded 61 species of Scarabaeinae belonging to three tribes from Bangalore in the Deccan region with 33 first reports from the locality; Biswas *et al.* (1997) recorded three species from Delhi; Chatterjee & Biswas (2000) recorded 27 species from Tripura State; Chandra (2000) made an inventory of Scarabaeid beetles of Madhya Pradesh and Chattisgarh; Chandra & Rajan (2004) reported *Onthophagus cervus* (Fabricius) from Mount Harriett National Park, South Andaman. Chandra & Singh (2004) recorded 10 dung beetles from Pachmarhi Biosphere Reserve, Madhya Pradesh. Forty nine species were reported from Gujarat (Sewak 2004).

Chandra (2005) collected 69 species of Scarabaeinae dung beetles from Western Himalaya of which 34 species belong to the genus *Onthophagus*. Chandra & Ahirwar (2005) recorded 34 species from Kanha Tiger Reserve, Madhya Pradesh. Rajan (2006) prepared a checklist of 88 dung beetles based on collections from 1997-2001 and provided species level keys to the dung beetles from Biligiri Rangaswamy Temple Wildlife Sanctuary, Karnataka. Sewak (2006) reported 73 species from Arunachal Pradesh of which 22 species were first records from the region. Sixty seven species of dung beetles along with their district-wise distribution was provided from Madhya Pradesh (Chandra & Ahirwar 2007).

Since the systematic studies on the dung beetles from the region by Arrow (1931), very few studies have assessed the taxonomy of dung beetles in Western Ghats. Though Arrow (1931) reported 48 species of dung beetles from the western slopes of the South Western Ghats, it is unable to decipher the habitats from which the beetles were collected as locality details were not provided along with site descriptions. Paulian (1980) reported five new species of Canthonines from South India namely; *Phacosoma nitidus*, *P. loebli*, *Panelus mussardi*, *P. besucheti* and *P. keralai*. Biswas & Chatterjee (1986) reported 3 new species namely; *Onthophagus keralicus*, *O. sahai* and *O. taruni* and recorded 16 species from the Silent Valley National Park.

A new genus *Cleptocaccobius* was introduced by Cambefort 1984 in the tribe Onthophagini. Cambefort (1985) revised the oriental species of *Cleptocaccobius* and four new species; *C. arrowi, C. khatimae, C. durantoni* and *C. boucomonti* and a new subspecies; *C. simplex* was described. Taxonomic and biogeographic status of genus *Drepanocerus* Kirby 1828 and the related genera is revised and discussed. *Afrodrepanus*, *Clypeodrepanus*, *Latodrepanus*, *Sulcodrepanus* and *Tibiodrepanus* were the new genera proposed (Krikken 2009).

Balthasar (1959) described *Digitonthophagus* as a subgenus of *Onthophagus* Latreille for the Indian species. Later Zunino (1981) revised *Digitonthophagus* and raised to genus level. Two new subgenera *Macronthophagus* and *Sunenaga* were proposed by Ochi 2003. Subgenus *Paracopris* Balthasar 1939 and *Euonthophagus* were raised to genus level. In tribe Gymnopleurini subgenus *Allogymnopleurus, Garreta* and *Paragymnopleurus* was raised to genus level in Löbl & Smetana 2006.

Chandra (2000) presents a checklist of scarabid beetles from Madhya Pradesh which total up to 94 taxa belonging to 9 subfamilies. Biswas & Mulay (2001) recorded 71 species from Nilgiri Biosphere Reserve. Mathew (2004) recorded 37 species from Kerala. A new species, *Onthophagus devagiriensis* from a moist deciduous forest in the Wayanad region of Kerala State was recorded (Schoolmeesters & Sabu 2006). Anu (2006) prepared a checklist of 29 species from a wet evergreen forest in the Wayanad region of Nilgiri Biosphere Reserve. Vinod (2009) prepared a checklist of 58 species, comprising 13 genera and 7 tribes of the Wayanad region. Taxonomy of dung beetle genus *Ochicanthon* Vaz-de mello (Coleoptera: Scarabaeidae) of the Indian subcontinent was revised and eight new species of *Ochicanthon* was provided by Latha *et al*. (2011). Seven new synonyms within the genus *Onthophagus* (Coleoptera: Scarabaeidae) from the oriental region was provided in which *Onthophagus anamalaiensis* was synonymised with *O. vladimiri* by Tarasov

2010. Sabu *et al*. (2011a) prepared a checklist of dung beetles from the moist South Western Ghats. Sabu *et al*. (2011b) provided a study on the cloud forest dung beetles in the Western Ghats. Chandra & Gupta (2012) present a new record of five species of genus *Onthophagus* viz. *Onthophagus abacus* Boucomont, *O*. *armatus* Blanchard, *O*. *rudis* Sharp, *O*. *gratus* Arrow and *O*. *amplexus* Sharp from Central India.

2.2. Ecology and biology of dung beetles in international level

The natural history of dung beetles of the sub family Scarabaeinae (Coleoptera, Scarabaeidae) by Halffter & Mathews (1966) and Dung beetle ecology by Hanski & Cambefort (1991a) are the two most inclusive works on the ecology of dung beetles. Natural history of dung beetle is an extensive work on food relationships, relations to the biome, feeding behaviour, sexual relationships and evolutionary trends of dung beetles where as ecology of dung beetles includes population biology, biogeography and evolution and comprehensive account on regional dung beetle assemblages of north (Hanski 1991) and south (Lumaret & Kirk 1991) temperate region, subtropical North America (Kohlmann 1991), South Africa (Doube 1991), tropical savannahs (Cambefort 1991), tropical forests in south east Asia (Hanski & Krikken 1991), tropical forests in Africa (Cambefort & Walter 1991), tropical American forests (Gill 1991), Sahel region of Africa (Rougon & Rougon 1991), montane dung beetles (Lumaret & Stiernet 1991) and native introduced dung beetles in Australia (Doube *et al*. 1991).

2.2.1. Functional guild composition

Cambefort & Hanski (1991) classified dung beetles into three functional guilds based on their feeding and nesting strategies namely; rollers (telecoprid nesters), tunnelers (paracoprid nesters) and dwellers (endocoprid nesters). Studies in functional guild composition of dung beetle assemblages of different habitats across the world includes studies done in forests of Colombia (Howden & Nealis 1975; Escobar 2000), forest pasture ecotones of Amazonia (Klein 1989; Vulinec 2000), moist forest of Ivory Coast in Africa (Cambefort & Walter 1991), Australia (Howden *et al.* 1991), Panama (Gill 1991), forest pasture ecotones of Mexico (Estrada *et al.* 1998, 1999), rain forests in Malaysia (Davis *et al.* 2000), Guyana (Feer 2000), Brazil (Andresen 2002), forest-savanna ecotone in Bolivia (Spector & Ayzama 2003), in natural and anthropogenic habitats of montane region of Colombia (Escobar 2004), in mountain grasslands of southern Alps (Errouissi *et al.* 2004), agriculture field in Guatemala (Avendaño-Mendoza *et al.* 2005), Indonesia (Shahabuddin *et al.* 2005), agriculture field of Wayanad (Sabu & Vinod 2005), in elephant and bison dung of moist forests in south Western Ghats (Sabu *et al.* 2006; Vinod & Sabu 2007), in continuous forests, forest fragments and cattle pastures of Chiapas, Mexico (Navarrete & Halffter 2008) and in forest, monoculture plantation and agriculture field of Wayanad (Vinod 2009).

Dominant guild in most assemblages was the tunnelers (Cambefort & Walter 1991; Hanski & Cambefort 1991a; Halffter *et al.* 1992; Escobar 2004; Sabu *et al.* 2006; Navarrete & Halffter 2008; Vinod 2009). Rollers were the second dominant guild preceded by tunnelers in the assemblages of Mexico (Estrada *et al*. 1998) and Tanzania (Nielson 2007). Rollers were not recorded in the agroecosystems of North India (Mittal & Vadhera 1998). Moist forests of Ivory Coast (Cambefort & Walter 1991) and Wayanad (Vinod 2009) were the only exceptions where the dominant species were distributed between tunneler and dweller guilds. Dwellers were found to be associated with large undisturbed herbivore dung pats (Hanski & Cambefort 1991a; Krell *et al*. 2003; Krell-Westerwalbesloh *et al*. 2004) the availability of which determines their presence. Surface crust formation in dung pats was found to reduce dweller abundance in summer (Doube 1991; Hanski 1991; Sowig & Wassmer 1994; Horgan 2001; Vinod 2009). Krell *et al*. (2003) found that the abundance of rollers and their kleptoparasites were positively correlated with the temperature of faeces and soil, whereas the number of dwellers increases with decreasing temperature during the exposure period.

2.2.2. Temporal guild composition

Temporal differentiation appears particularly relevant in tropical forests where high rates of exploitation of carrion and dung occur especially because the resource is presumably limited (Peck & Forsyth 1982; Klein 1989; Feer 1999). Hanski (1990) reported that success of any dung beetle species is determined by their early arrival at the resource; hence diel activity of species is an important parameter determining their success. Diel resource partitioning within dung beetle assemblages have been studied several times (Fincher *et al*. 1971; Peck & Forsyth 1982; Janzen 1983; Walter 1985; Hanski 1986;

Cambefort 1991; Cambefort & Walter 1991; Doube 1991; Gill 1991; Caveney *et al*. 1995; Davis 1999; Krell *et al*. 2003; Krell-Westerwalbesloh *et al.* 2004; Feer & Pincebourde 2005).

In tropical ecosystems, species compositions of diurnal and nocturnal dung beetle assemblages were clearly different (Hanski & Cambefort 1991a), particularly in open habitats (Cambefort & Walter 1991).

Dung beetles were generally found to show an abundance peak at dusk and around mid day (Peck & Forsyth 1982; Walter 1985; Fincher *et al*. 1986; Davis 1996a; Davis 1999; Feer 2000). Light intensity was found several times to be responsible for the onset of flight of crepuscular dung beetles (Carne 1956; Houston & McIntyre 1985). In Africa, Walter (1985) distinguished various temporal patterns among diurnal and nocturnal species. In Panama, diurnal species display several distinctive patterns of flight activity and some species are possibly auroral/crepuscular (Howden & Young 1981; Gill 1991) or active both by night and day. A similar grouping of species by temporal activity seems to prevail also in French Guiana (Feer 2000). Krell-Westerwalbesloh *et al.* (2004) reported different patterns of guild structure during the day, with time of day and temperature influencing the presence of guilds.

Diurnal species tend to be smaller than nocturnal and crepuscular species and nocturnal species are black or dark in body colour whereas diurnal species show colour patterns (Feer & Pincebourde 2005). Diurnal species were more numerous than nocturnal species in several studies (Hanski 1989; Gill

1991; Davis 1999; Andresen 2000; Feer & Pincebourde 2005) but equal or higher numbers of nocturnal species exist in other forests (Cambefort 1984; Walter 1985; Howden *et al*. 1991; Halffter *et al*. 1992; Escobar & Chacon de Ulloa 2000). Navarrete & Halffter (2008) reported that large bodied, nocturnal species with specific requirements of soil temperature and compaction are more sensitive to anthropogenic changes.

2.2.3. Species diversity

Diversity of dung beetle assemblages and species richness were studied in tropical rain forests of southeast Asia (Hanski 1983; Hanski & Krikken 1991; Davis *et al*. 1997; Davis 2000a), forests of Australia (Howden *et al*. 1991; Vernes *et al*. 2005), rain forests of Africa (Cambefort & Walter 1991), agriculture fields of north India (Mittal & Vadhera 1998), forest pasture ecotones of Mexico (Estrada *et al*. 1998), forests of Malaysia (Davis 2000a), forests of Colombia (Escobar 2000), French Guyana (Feer 2000), temperate North America (Lobo 2000), Peru (Valencia *et al*. 2001), rain forests of Mexico (Estrada & Coates-Estrada 2002), Columbia (Escobar 2004), agroecosystems of Guatemala (Avendaño-Mendoza *et al*. 2005), Sulawesi, Indonesia (Shahabuddin *et al*. 2005), Africa (Nielson 2007), in natural and modified habitats in southern Mexico (Arellano *et al*. 2008) in forest, in Chiapas, Mexico (Navarrete & Halffter 2008), monoculture plantation and agriculture field of Wayanad (Vinod 2009).

Jameson (1989) compared dung beetle communities in grazed and ungrazed habitats of western Nebraska and observed slightly higher diversity on the grazed site. Klein (1989) found that forest fragments in Central Amazonia had reduced richness and abundance of dung beetles when compared to the continuous forest. Galante *et al*. (1991) found that smaller species inhabited open pasture lands when compared to the adjacent woodlands. Abundance declines with increasing disturbance but partially modified habitats showed few differences in Scarabaeinae biomass between undisturbed and secondary grown forest (Vulinec 2000; Scheffler 2005; Vulinec *et al.* 2006). Horgan (2002) studied dung beetle communities in shaded and open habitats and reported the importance of soil moisture in determining dung beetle activity.

Habitat structural complexity and resource availability are important factors in determining the dung beetle community (Neves *et al*. 2010). Studies by Andresen (2005) in tropical dry forests pointed out that change in community organization of dung beetles can include changes in species richness, species composition, abundance and guild structure. In a comparative study on the dung beetle communities in cloud forest and coffee agroecosystems, Pineda *et al*. (2005) recorded significantly higher species richness and abundance in coffee plantations. Harvey *et al*. (2006) compared the abundance, species richness and diversity of dung beetles across a gradient of different land use types, from agriculture monocultures (plantains) to agroforestry systems (cocoa and banana) and forests in two indigenous reserves in Costa Rica. Dung beetle species richness and diversity were greatest in the forests, intermediate in the agroforestry systems and lowest in the plantain monocultures; while dung beetle abundance was greatest in the plantain monocultures. Lobo *et al*. (2006) analysed regional and local influence of grazing activity on the diversity of a semi-arid dung beetle community and found that grazing intensity and the associated increase in the amount of trophic resources (dung) is a key factor in determining local variation in the diversity and composition of dung beetle assemblages. Andresen & Laurence (2007) reported lower species richness and abundance in Panamanian rainforest due to increased hunting of mammals. Shahabuddin (2010) recorded significant decrease in species richness of dung beetles from natural forests to open area. Dung beetle community changed between dry and wet seasons, with a dramatic decrease in species richness and abundance in the dry season. Dry Tropical Forests probably have the most pronounced intra-annual differences in dung beetle communities among all tropical forested ecosystems, since these organisms all but cease activity during the dry season (Neves *et al*. 2010).

2.2.4. Indicators of habitat modification

Reports on dung beetle species response to destruction, fragmentation and isolation of tropical rain forests are available from Central and South America (Howden & Nealis 1975; Peck & Forsyth 1982; Klein 1989; Halffter *et al*. 1992; Horgan 2002; Andresen 2003, 2005, 2007; Durães *et al*. 2005; Scheffler 2005), Africa (Cambefort 1984), Malaysian rainforests (Davis 2000b; Davis *et al*. 2001). Studies reported important negative effects such as, fewer species and sparser populations as a result of clear-cutting (Howden & Nealis 1975; Klein 1989; Estrada *et al*. 1998; Horgan 2002; Krell *et al*. 2003). Habitat modifications was found to affect functional guild composition in Columbian rainforest which was earlier described with high dweller abundance (Howden & Nealis 1975), but showed an entirely different guild structure in more recent reports with low presence of dwellers (Escobar 2000), which is probably related to the extensive deforestation of Amazonian forests (Anderson 1990; Skole & Tucker 1993). Howden & Nealis (1975) recorded that dung beetle species did not move between forest and man made clearings which is mainly attributed to temperature difference between the two habitats in Colombia. Hill (1996) demonstrated high degrees of biotope specificity related to vegetation type in dung beetle species in rain forest and more open areas in north-eastern Australia. Jankielsohn *et al*. (2001) observed habitat specificity related to soil temperature due to shaded and unshaded condition in South Africa. Scheffler (2002) reported that though some species can utilize more than a single habitat type, certain species may never be found outside their preferred habitat. Durães *et al.* (2005) found effect of habitat on the distribution of forest and grassland species of dung beetles in Brazil. Andresen (2005) recorded how forest structure determined dung beetle community organization in Mexican tropical dry forest. Diaz *et al*. (2010) noted high habitat specificity in beetles in dissimilar habitats in Mexico.

Klein (1989) documented the effects of forest fragmentation on insects in the tropics, and recorded dung beetle communities in 1-ha and 10-ha forest fragments differed from those in contiguous forest, even though the fragments had been isolated by less than 350 m for an ecologically short time (2–6 years).

Nummalin & Hanski (1989) compared dung beetle species assemblages of virgin and managed forests in Africa. Deforested places were found to be less species rich, their evenness and biomass decline and there is an abundance of few small- bodied species (Klein 1989; Halffter *et al.* 1992, 2007; Halffter & Arellano 2002; Avendaño-Mendoza *et al.* 2005; Pineda *et al.* 2005; Quintero & Rosalin 2005).

Davis *et al*. (2001) conducted detailed studies on effect of habitat disturbance and species abundance distributions of dung beetles from the south east Asian region. During a historical compilation of data on roller dung beetle occurrence in the Iberian Peninsula between the first and second half of the 20th century, Lobo (2001) reported the decline of roller dung beetles as a result of urban development. Roslin & Koivunen (2001) found that different species show very dissimilar responses to changes in landscape structure.

With the aim of determining what kind of landscape mosaics might sustain maximum diversity and minimum species loss, Estrada & Coates-Estrada (2002) sampled dung beetles in a tract of continuous forest, forest fragments and a habitat island consisting of mosaic of forest and arboreal crops in Mexico. Continuous forest showed increased abundance. Studies proved that these consequences are primarily related to modification of natural vegetation (Estrada & Coates-Estrada 2002; Halffter & Arellano 2002) and the loss of indigenous mammals, primarily large monogastric taxa that void large, fibrous droppings (Owen-Smith 1983; Davis 2002). Hutton & Giller (2003) analysed the effect of intensification of agriculture on dung beetles in temperate region.

Anduaga (2004) assessed the impact of the activity of dung beetles in the pasture land in Mexico. In a study which analyzed the diversity and composition of the dung beetle assemblages in natural and anthropogenic habitats- primary forest, secondary forest, pasture and crop land. Escobar (2004) found that the creation of new environments such as cropland and pasture favours the presence of the few forest species that can tolerate the modification of their habitat and also allows for colonization by non-forest species that arrive from other regions.

Studies in Mexican and Central American cloud forests and adjacent shaded coffee plantations demonstrated that some types of land use and agricultural practices, such as shaded cropland provide a buffer for various taxonomic groups against the damage caused by the transformation of native forest (Pineda & Halffter 2004). Diversity of dung beetles in a disturbed Mexican tropical montane cloud forest and in shade coffee plantations were studied (Arellano *et al*. 2005). All habitats had similar richness, species composition and assemblage structure of dung beetles. Species composition differences were influenced by functional guilds and beetle size according to temporal segregation (Medina & Lopes 2014). Pineda *et al*. (2005) demonstrated that a matrix habitat with a structure partly similar to the original vegetation may help to sustain diverse dung beetle assemblages in the fragments and even within the matrix itself.

Quintero & Rosalin (2005) assessed how rapidly dung beetle communities recover following rain forest loss and fragmentation through the preservation of forest fragments and secondary vegetation. The reduction in species richness and diversity in disturbed habitats was mainly influenced by the arboreal nature of the matrix (Quintero & Rosalin 2005; Avendaño-Mendoza *et al.* 2005; Halffter *et al.* 2007). They also reported increase in roller guild with increase in anthropogenic disturbance in Chiapas, Mexico.

Severe disturbances such as clear-cutting and conversion to pasture results in abundance of small-bodied beetles, a notable decline in beetle species richness and diversity and a change in species composition in Amazonian forests (Scheffler 2005). Shahabuddin *et al*. (2005) found that dung beetle fauna of the natural forest appeared to be relatively robust to manmade habitat changes and majority of species did not exhibit strong habitat preferences. Studies done by Botes *et al*. (2006) recorded that dung beetle diversity was lower in human- disturbed Sand forest compared to undisturbed Sand Forest in Africa.

In Peru, forest fragments and small isolated patches of native trees and shrubs maintained some of the diversity of the original landscape in cattle pastures (Horgan 2007). Gardner *et al.* (2008) reported low value for secondary forest for offsetting dung beetle species loss. From an overview of published materials on dung beetle ecology, Navarrete & Halffter (2008) reported loss of species richness in disturbed habitats along a disturbance gradient namely undisturbed forest to clear-cuts.

Nyeko (2009) found dung beetle abundance higher in larger fragments (100–150 ha) than in the smaller ones (10–50 ha) in sub-Saharan Africa.

Quintero & Halffter (2009) in Manaus, Brazil found recovery of dung beetle population in forest fragments due to development of secondary vegetation which formed connectivity between fragments and the continuous forest. Studies done in Wayanad also revealed decreased species richness and diversity in modified habitat when compared to natural forests (Vinod 2009). Ecosystem function especially dung burial activity were remarkably disrupted by land use changes from natural forest to open agricultural area in Sulawesi, Indonesia (Shahabuddin 2011).

2.2.5. Seasonality

Several studies have been done on seasonality in dung beetles in southern Europe (Krausse 1907a, b; Lumaret 1983), forests of Barro Colorado Island, Panama (Howden & Young 1981), Neotropics (Janzen 1983; Andresen 2005); south western Australia (Ridsdill-Smith & Hall 1984a, b) south western Cape (Davis 1987), southeast Asia (Paarmann & Stork 1987), Africa (Doube 1991; Rougon & Rougon 1991) and southeast Asia (Hanski & Krikken 1991).

Kingston (1977) reported extreme seasonality of dung beetles in African savanna. In a more seasonal forest on Barro Colorado Island, Panama different pattern of seasonality was observed. Most species of Scarabaeinae occur throughout the year or are more abundant in the wet season and one or two species appear to be restricted to dry season (Howden & Young 1981). Howden & Young (1981) also noticed that many species are most abundant in particular phases of the wet season. Peck & Forsyth (1982) observed no marked seasonality in an Ecuadorian rain forest with no severe dry season. In a deciduous Costa Rican forest with six month dry season, dung beetle activity was markedly seasonal (Janzen 1983).

In forests of Ivory Coast, scarab numbers followed bimonthly rainfall patterns rather closely (Cambefort 1984). Dung beetle seasonality suggest that activity is greatest during moist and minimal during dry periods and the abundance of scarab beetles increases strongly after heavy rainfall (Walter 1985; Doube *et al.* 1991; Hanski & Krikken 1991; Andresen 2005). Edwards (1991) studied the influence of seasonal variations in the dung of grazing mammals on dung beetles in a summer-rainfall forest in South Africa. Both Hill (1993) and Wright (1997) demonstrated that most species in tropical Australia were found only in the wetter months. Seasonal activity of dung beetles associated with cattle dung was studied (Floate & Gill 1998; Bertone *et al*. 2005). A comparison of seasonality of coprophagous beetles in bovine dung was conducted by Morelli *et al*. (2002). Deloya *et al*. (2007) found that beetle activity increased with precipitation in Veracruz, Mexico. Vinod (2009) reported peak in species richness during the post rainy or presummer period in contrast to the seasonality pattern of other forest dung beetle assemblages, where peak in richness was recorded during the wet rainy period (Janzen 1983; Andresen 2005; Vernes *et al*. 2005).

2.2.6. Ecology and biology of dung beetles in India

Few studies address the ecology of dung beetles in the Indian subcontinent. Hingston (1923) made observations on Indian dung beetles and reported the role of these nature’s scavengers in the removal of excrement of men and cattle, in his ‘A naturalist in Hindustan’. Oppenheimer (1977) reported low abundance of rollers in Bengal. Ecology and community structure of dung beetles in the urban and agricultural landscapes of northwest India were analyzed by Mittal during 1981-2005 period. He analyzed various aspects of dung beetles namely; distributional trends (Mittal 1981), attraction towards human faeces (Mittal 1986), natural manuring and soil conditioning (Mittal 1993), food preferences (Mittal & Bhati 1998), succession and community structure of dung beetles attracted to cow dung (Mittal & Vadhera 1998) and community dynamics, diversity and conservation status (Mittal 2005; Mittal & Kakkar 2005) in agricultural landscapes of northwest India. According to Mittal (2005) as a result of the occurrence, abundance and distribution of dry habitat with West Indian region have changed during the 30 years of study. Factors related to arid environments can induce changes to dung beetles community structure, mainly through a reduction in species richness and changes in species composition (Hernández 2005; Lopes & Louzada 2005; Lopes *et al*. 2006; Hernández 2007; Liberal 2008; Neves *et al*. 2010; Liberal *et al*. 2011). Loss of the habitat in urban and rural areas, and the altered food quality because of pollutants and the increased use of cattle antibiotics are the major causes for the decline in the diversity.

Few studies on the biology of dung beetle from south Indian region exists and details are as follows; studies on the feeding and breeding behavior of *Gymnopleurus gemmatus* Harold and *Gymnopleurus miliaris* (Fabricius) with details of feeding, ball making and rolling, mating, competition and predation (Veenakumari & Veeresh 1996a); subsociality in *Copris repertus* Walker and *Copris indicus* Gill (Veenakumari & Veeresh 1997); reproductive biology of the two commonly occurring South Indian species- *Onthophagus gazella* (Fabricius) and *Onthophagus rectecornutus* Lansberge (Veenakumari & Veeresh 1996b); SEM study of the stridulatory organs with observations on the significance of the sound production in the giant dung beetle *Heliocopris dominus* Bates (Joseph 1991), sexual dimorphism and intra sex variations (Joseph 1994), biology and breeding behavior (Joseph 1998) and the life cycle, ecological role and biology of immature stages of *Heliocopris dominus* (Joseph 2003).

Studies on the ecology and community structure of dung beetles in South Western Ghats are minimal. Sabu & Vinod (2005) analysed the guild structure and taxonomic diversity of two dung beetle assemblages in intact forest and nearby pasture in North Wayanad. Sabu *et al*. (2006) analysed the guild structure, diversity and succession of dung beetles associated with Indian elephant dung in the forests of Thirunelly in South Western Ghats. In another similar study, Vinod & Sabu (2007) compared the species composition and community structure of dung beetles associated with the dung of gaur and elephant from the same locality. Succession of dung beetles in the dung pats of gaur, from the moist deciduous forests of Southern Western Ghats was also studied (Sabu *et al*. 2007). Vinod (2009) provided data on the systematics and ecology of dung beetles in the forest and agricultural habitat in the Wayanad region of South Western Ghats. Comprehensive data on the community structure, species composition and regional endemism of dung beetle assemblage in a tropical montane cloud forest (TMCF) from South Asia was provided by Sabu *et al.* (2011b).

Detailed analysis of the literature revealed that no work is available on dung beetle taxonomy and ecology of dry forests in India and specifically the Western Ghats; hence the present study gains significance.

Chapter 3

MATERIALS AND METHODS

3.1. Study site

The study was carried out at a southern tropical thorny forest at Chinnar Wildlife Sanctuary located in the eastern slope of south Western Ghats in South India (Plate 1). The sanctuary is located 54 km south to Munnar, Marayoor and Kanthaloor panchayathas of Devikulam taluk in Idukki district. It is one of the 12 Wildlife Sanctuaries among the protected areas of Kerala. The habitat types arrange from high altitude shola grassland to dry thorny scrub.

Chinnar Wildlife Sanctuary is a rain shadow region of Western Ghats and it represents a large number of plants and animals unique to the thorny vegetation exist here. Apart from the dry thorny forests, due to the significant variation in altitude and rainfall, it has a wide array of habitat types like deciduous forests, riparian types, sholas and grasslands that are interspersed with plains, hillocks, rocks and cliffs which provide microhabitats for varied forms of life. Chinnar wildlife sanctuary (10º 15' to 10º 21' N latitude and 77 º 05’ to 77 º 16’ E longitude) contains an area of 90.422 sq kms. Altitude varies from 500 m to 2500 m within a few kilometer radius. Chinnar gets only about 48 rainy days in a year during October- December (North - East Monsoons). Temperature varies from 0°C to 30°C in winter and 24°C to 35°C in summer seasons. Average annual rainfall is only 300–500 mm, spread over about 48 days. According to the rainfall data, there are only two seasons, dry season (January to September) and north-east monsoon (October to December). The rainfall regime of the Sanctuary is characterized by the highly variable precipitation linked with the cyclonic disturbances affecting the Bay of Bengal during the withdrawal of monsoon. The study was carried out in the thorny forest area of Chinnar Wildlife Sanctuary (10º 31' N, 76º 40' E) at an elevation of 300 msl. The temperature of the area is influenced by the Coimbatore-Mysore thermic regime. The temperature is relatively constant from July to October. The recorded lowest temperature is 12°C and the highest is 38°C with mean annual temperature of 36°C. On the slopes below 650 m of south Western Ghats the dry deciduous formation is generally thorny (Ramesh 2003). A thorny forest is a dense, scrub like vegetation characteristic of dry subtropical and warm temperate areas with a seasonal rainfall averaging 250 to 500 mm. The open low forest type is characterized by xerophytic species with short bole and low branching. The canopy is wide open; therefore the canopy level differentiation is indistinguishable. The hardwood trees, thorny shrubs and climbers are characteristic features of the forest type. The trees in southern tropical thorn scrub forests attain a height of 6 to 9 meters. The undergrowth is furnished with some herbaceous forms during monsoon and remains exposed for the rest of the time. Thorny forest is the second major forest type in the Chinnar wildlife Sanctuary with regard to the area (Plate 2). The dry open scrub forests of Chinnar Wildlife Sanctuary provide an excellent habitat for a wide variety of mammals, birds, butterflies and reptiles. Grizzled Giant Squirrel is common in this region. Apart from the rare rusty spotted cat and Nilgiri tahr (*Nilgiritragus hylocrius*), the important mammals found in the Sanctuary are elephant (*Elephas maximus* Linnaeus, 1758) tiger (*Panthera tigris* Linnaeus, 1758), leopard (*Panthera pardus* Linnaeus, 1758), bison (*Bos* *gaurus* C.H. Smith, 1827), wild boar (*Sus scrofa* Linnaeus, 1758), sambar deer (*Cervus unicolor* Kerr, 1792), barking deer (*Muntiacus muntjak* Zimmermann, 1780), wild dog (*Cuon alpines* Pallas, 1811), common langur (*Macaca mulatta* Zimmermann, 1780), bonnet macaque (*Macaque radiate* Pocock, 1931), jackal (*Canis aureus* Linneaeus, 1758), sloth bear (*Melursus ursinus* Shaw, 1791), Nilgiri langur (*Trachypithecus johni* Fischer, 1829), jungle cat (*Felis chaus* Schreber, 1777), etc.

The major species representing the flora of the forest type are *Acacia* spp. (*Acacia arabica* (Karivelam), *Acacia leucofolia* (Velvelam), *Acacia concinna* (Cheevaka)), *Euphorbia* spp., *Capparis* spp., *Opuntia* spp., *Ziziphus* spp., *Grewia* spp., *Cordia* spp., *Caralluma* spp., *Helixanthera* spp., *Albizia amara* (Roxburgh, 1838), *Atalantia monophylla* (Linnaeus, 1824), *Pleiospermium alatum* (Wight & Arnott, 1916), *Prosopis juliflora* (Swartz, 1825), *Dichrostachys cinerea* (Linnaeus, 1834), *Diospyros cordifolia* (Roxburgh, 1795), *Pisonia aculeate* (Linnaeus, 1753), *Carissa carandas* (Linnaeus, 1767), etc.

3.2. Sampling methodology

Dung beetles were collected using dung baited pitfall traps (Plate 2) of the bait-surface-grid type (Lobo *et al*. 1988; Veiga *et al*. 1989) Since, dung beetles are excellent fliers and actively forage for food, they can be efficiently sampled using baited pit fall traps (Larsen & Forsyth 2005), pitfall traps also provide fast, inexpensive, and relatively unbiased method for obtaining data on species diversity and abundance distributions (Spector & Forsyth 1998). Dung beetles were collected on a seasonal basis in dry season (January to September) and north-east monsoon (October to December) during 2009–2012 period.

Traps were laid out in two transects at 50 m intervals with 450m trap lines, each contains 10 traps following the standardized dung beetle sampling design of maintaining a minimum distance of 50 m between the traps to minimize the trap interference (Larsen & Forsyth 2005). Pitfall traps consisted of a plastic bowl having 21 cm diameter and 15 cm depth, buried up to its rim in soil without making any disturbance in the habitat. Each pitfall traps was partly filled with solution of mild detergent (to reduce surface tension and facilitate rapid drowning of the beetles) and salt (to reduce deterioration of the specimens) (Spector & Ayzama 2003) and roofed with a dark plastic sheet supported on iron bars; it prevents either desiccation or flooding and also prevents the entry of falling leaves or debris or anything which may facilitate escape of the trapped fauna. Two hundred gm of fresh dung of boar was placed on a strip of wire grid at the top of the basin as bait.

The trap contents were collected at 12 h interval (6:00–18:00 h and 18:00–6:00 h) to separate diurnal and nocturnal species because flight activity of dung beetles differs strongly between night and day at the guild level (Krell *et al*. 2003). Both diurnal and nocturnal collections were collected separately. Traps were emptied into a fine nylon gauze (0.5 mm mesh size), to concentrate the catches from the traps. An ethanol filled wash bottle was used to wash the catch into labelled bottles.

3.3. Preservation and Identification

Collected beetles were preserved in 70% alcohol overnight and later identified to species level using taxonomic keys available in Arrow (1931) and Balthasar (1963a, b) also by verifying with type specimens available in the Coleoptera collections of St. Joseph's College, Devagiri, Calicut. Once identified to the species level, the specimens were separated and kept in small vials containing 70% alcohol, appropriately labelled with information on site location, trapping date, taxon name, trap type and number. Specimens were subsequently curated in the insect collections of St. Joseph's College, Devagiri, Calicut and allotypes of rare specimens would be deposited in the museums of Zoological Survey of India, Western Ghats regional station, Calicut.

Number of species and number of individuals for each season were noted. Functional guilds viz., dwellers (endocoprids), rollers (telecoprids) and tunnelers (paracoprids) were identified following Cambefort & Hanski (1991). For identifying temporal guilds viz., diurnal, nocturnal (Krell *et al.* 2003; Krell-Westerwalbesloh *et al.* 2004) and generalists, data was obtained by pooling diurnal/nocturnal collection for three seasons. Species that were collected only in diurnal traps or nocturnal traps were designated as diurnal or nocturnal. For those that were collected in diurnal and nocturnal collections, significant levels of variation in species abundance were calculated. Species showed no variation in nocturnal and diurnal collection was considered generalists and those species showed significant variation was taken as diurnal or nocturnal. All data were entered in Microsoft Excel work sheet (2003).

3.4. Checklist and Pictorial Key

Checklist was prepared based on the species collected during the present study. Pictorial key was drafted based on Arrow (1931), Balthasar (1963a, b) and Schoolmeesters & Sabu (2006). Photographs were taken using Nikon D50 digital camera attached to a trinocular stereo zoom microscope (Labomed, ASZ-99TR).

3.5. Diversity analysis

To understand the diversity patterns, alpha diversity indices (richness, diversity, dominance and evenness) and rank abundance plot were done.

For analyzing species richness, Margalef's index (d) (Clifford & Stephenson 1975; Magurran 2004) was calculated by using the following formula.

$$d = S - 1 / \log (N)$$

S = total number of species

N = total number of individuals

Among the diversity indices, Shannon-Weaver diversity index (Shannon & Weaver 1949) is the most commonly used because it incorporates both species richness and evenness components and can provide heterogeneity of information (Rosenstock 1998; Cheng 1999).

$$H' = - \Sigma_i P_i (\log (P_i)$$

Where P_i is the proportion of the total count arising from the i^{th} species ($\log_e$ was used in its formulation).

Simpson's dominance index (λ) (Simpson 1949) gave the probability of any two individuals drawn at random from an infinitely large community belonging to the same species, its largest value correspond to assemblages whose total abundance is dominated by one or a very few of the species present.

$$\lambda = \Sigma\, p_i^2$$

Where p_i is the proportion of the total count arising from the i th species

Evenness expressed as Simpson's evenness index (1-λ), addresses equitability of the species (Simpson 1949).

$$\lambda = 1 - \Sigma\, p_i^2$$

Although there are many possible indices which can be used to portray diversity, each with strengths and weaknesses, these four are chosen because they are familiar to and readily interpretable for most ecologists. All diversity analysis was done with PRIMER 5 software version 5.2.9 (Clarke & Gorley 2001).

3.6. Statistical analysis

All the data used for statistical analysis were tested for normality with Anderson-Darling test. Since all the data were not normally distributed non-parametric statistics, Kruskal-Wallis H tests was used to test the significance levels of variation in abundance (Sachs 1992). Differences with a p-value <0.05 was compared using Wilcoxon-Mann/ Whitney Test. The data includes the abundance of individual species of dung beetles; seasonal abundance of individual species of dung beetles; variations in functional guild abundance with seasons and variations in temporal guild abundance with seasons. All statistical analyses were performed using Megastat version 10.0 (Orris 2005).

Plate 1: (A) Map of Kerala state and (B) Idukki district showing the study region.

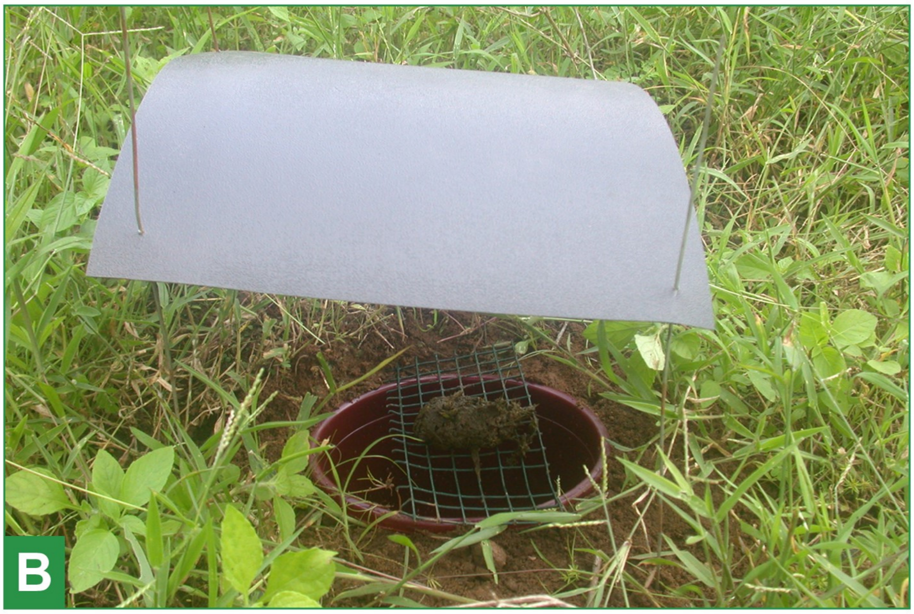


Plate 2: (A) Thorny forest at Chinnar region and (B) Pitfall trap method.

Chapter 4

RESULTS

4.1. Taxonomy

Thirty Five species, comprising 13 genera namely; *Caccobius*, *Catharsius*, *Cleptocaccobius*, *Garreta*, *Gymnopleurus*, *Heliocopris*, *Onthophagus*, *Paracopris*, *Paragymnopleurus*, *Scarabaeus*, *Sisyphus*, *Tibiodrepanus* and *Tiniocellus* belonging to six tribes namely; Coprini, Gymnopleurini, Oniticellini, Onthophagini, Scarabaeini and Sisyphini were recorded. *Onthophagus* with 14 species and *Caccobius* with six species were the most speciose genera.

First report of female of *Garreta smaragdifer* Walker, 1858 from India (Plate 3a & b) and first record of *Caccobius rufipennis* (Motschulski, 1858), from the Western Ghats, India are the major findings (Plate 3c).

***Garreta smaragdifer* Walker, 1858**

Head strongly rugose with short setae at the anterior part, coriaceous in front. Clypeus produced in to four angular lobes with two middle ones more prominent with upright brownish hairs fading out backwardly. Antennae dark brown in colour. Base of pronotum marked with a small median elongated impression in female and without in male. Elytra with fine punctures, intervals weakly convex with finely and evenly distributed punctures. Pygidium punctured without setae. Venter with a longitudinal depressed midline and with coarse granulation on lateral sides between mid and hind coxae. Phallobase of aedeagus with dorsal hump, junction of phallobase and parameres membranous (Figure 5-6). Short brownish setae close upon the clypeal region. Ventral body setae long and brownish.

Sexual dimorphism: male with terminal spine of the hind tibia more strongly curved and front tibiae less curved. Pronotal and elytral surface with more punctuation in male. Clypeal tooth pointed in male and rounded in female. Apical spur of front tibia long and sharp in female, truncate and flat in male.

Measurements (in mm; 1 female): TL=17.5, EL=10, PL= 6, PW=5.5; (1 male): TL=15, EL=8, PL=4, PW=3.5.

Distribution: India (Kerala: Chinnar); Sri Lanka (Mahailluppalama, Negombo).

***Caccobius (Caccobius) rufipennis* (Motschulsky, 1858)**

Description of the species is given in Arrow (1931) and Balthasar (1963). It has antennae with eight segments. It was earlier reported from Sri Lanka (Arrow 1931), and periphery of Eastern Ghats from India (Priyadarsanan 2006). First record of the species is achieved in the present study.

Distribution: India (Karnataka: BRT hills, Kanneri; Kerala: Chinnar); Sri Lanka: Colombo; Yala.

Among the 35 species recorded, 4 species namely; *Caccobius gallinus* Arrow, 1907; *C. rufipennis* (Motschulski, 1858); *Garreta smaragdifer* Walker, 1858 and *Paracopris davisoni* (Waterhouse, 1891) were endemic to the Western Ghats and three species namely; *Caccobius rufipennis* (Motschulski, 1858), *Garreta smaragdifer* Walker, 1858 and *Scarabaeus sanctus* Fabricius, 1798 were rare (Plate 3 & 4).

4.1.1. Check list of dung beetles of Chinnar region

Synonymies for genera and species are provided. Superscript provided to species furnishes the following details namely; #first report from India and Western Ghats, @endemic to Western Ghats and *rare in Chinnar region.

SCARABAEINAE

SCARABAEINI

***Scarabaeus* (Linnaéus, 1758)**

Scarabaeus Linnaéus, 1758, X: 345; 1767, XII: 541; Lansberge, 1874; Bedel, 1892; 281; Reitter, 1892 (1893); 37, 40; Péringuey, 1900 (1901): 23; Arrow, 1931: 38; Portevin, 1931: 40; Porta, 1932: 406; Balthasar, 1935: 28; Stolfa, 1938: 141; Janssens, 1940: 1; Paulian, 1941: 50; Balthasar, 1963, I: 144–145.

-*Actinophorus* Creutzer, 1799: 79.

-*Ateuchus* Weber, 1801: 10; Fabricius, 1801: 54; Lacrodaire, 1856, III: 66; Shipp, 1894, 27: 254, 289, 309; 1895: 218;

-*Heliocantharus* Mac Leay, 1821, I (2): 497; Mac Leay, 1833: 49;

-*Sebasteos* Westwood, 1847, IV: 226; Péringuey, 1900 (1901): 26, 57; Janssens, 1940: 5, 14; Kolbe, 1895, 56: 333;

-*Ateuchetus* Bedel, 1892: 282, 283; Reitter, 1892 (1893): 41;

-*Parateuchus* Shipp, 1895, 28: 221.

- subg. *Kheper* Janssens, 1940 14, 59; Balthasar 1940: 67; Janssens, 1941: 7.

***Scarabaeus* (*Kheper*) *sanctus** Fabricius, 1798**

Scarabaeus (*Kheper*) *sanctus** Fabricius, 1798: 34 (*Copris*); Fabricius, 1801: 56 (*Ateuchus*); Castelnau, 1840: 65 (*Ateuchus*); Arrow, 1931: 45; Janssens, 1940: 66, 73; Balthasar, 1963, I: 173.

Distribution: India (Bihar; Karnataka: Bangalore, Belgaum; Kerala: Nilgiri hills; Maharashtra: Mumbai; Orissa: Sholapur), Sri Lanka (Kinavallore).

***Scarabaeus* (*Kheper*) *erichsoni* Harold, 1867**

Scarabaeus (*Kheper*) *erichsoni* Harold, 1867, II: 94; Arrow, 1931: 45; Janssens, 1940: 66, 73; Balthasar, 1963, I: 173.

Distribution: India (Karnataka: Bangalore; Tamil Nadu: Madras; Kodaikanal; Podanur), Sri Lanka (Colombo, Kandy).

GYMNOPLEURINI

***Paragymnopleurus* Shipp, 1897**

Paragymnopleurus Shipp, 1897, XXX: 166 (*pro parte*); Balthasar, 1935: 47; Janssens, 1941, XVIII: 1–22; Garreta, 1941, XIX: 52; Paulian, 1945: 51. - subg. *Paragymnopleurus* Balthasar, 1963, I: 177–182, 189–190.

***Paragymnopleurus sinuatus* Olivier, 1789**

Paragymnopleurus sinuatus Olivier, 1789, I: 160; Arrow, 1931: 63; Balthasar, 1935: 47; Janssens, 1940, XVIII: 20; Leei Donovan, 1798; Paulian, 1945: 53.

Distribution: India (Arunachal Pradesh; Karnataka; Kerala: Nelliampathi, Nilambur, Palghat, Ranipuram, Shendurney; Maharashtra: Kanara, S. Bombay; Sikkim; W. Bengal), Myanmar, Nepal.

***Gymnopleurus* Illiger, 1803**

Gymnopleurus Illiger, 1803, II: 199; Latreille, 1807, II: 78; Lacordaire, 1856, III: 72, 73; Reitter, 1892/93: 37, 42; Shipp, 1897, XXX: 62, 166; Kolbe, 1897: 135; Péringuey, 1900/01: 22, 64; Garreta, 1914: 51, 55; Boucomont and Gillet, 1921: 3; Arrow, 1931: 46; Portevin, 1931: 40; Porta, 1932: 407; Balthasar, 1935: 38; Janssens, 1938: 30; Janssens, 1940a: 40 (ex parte); Paulian, 1941: 53; Balthasar, 1963, I: 177.

***Gymnopleurus* (s. str.) *cyaneus* (Fabricius, 1798)**

Gymnopleurus (s.*str*) *cyaneus* Fabricius, 1798: 34 (*Copris*); Macleay, 1821, 2: 515; Arrow, 1931: 49; Janssens, 1940a: 53–66; Balthasar, 1963, I: 207.

-*indicus* Castelnau, 1840: 73; Gillet, Q911: 314;

-*impressus* Castelnau, 1840: 73.

Distribution: Bangladesh, India (Andhra Pradesh; Gujarat; Haryana; Karnataka: Anaimalai hlls; Kerala: Malabar, N. Malabar; Maharashtra: Mumbai; Tamil Nadu: Coimbatore; W. Bengal: Dhoni forest, Kannirode), Sri Lanka.

***Garreta* Janssens, 1940**

Garreta Janssens, 1940a, 15, 22; Paulian, 1945: 50.

-subg. *Garrtta* Balthasar, 1963, I: 177, 180, 182–183, 188–189.

***Garreta smaragdifer*[#@]* Walker, 1858**

Garreta smaragdifer[#@]* Walker, 1858, II: 208; Arrow, 1931, III: 60; Janssens, 1940a: 24–29

- *Gymnopleurs smaragdifer* Balthasar, 1963, I: 226.

Distribution: India (Kerala: Chinnar), Sri Lanka.

SISYPHINI

***Sisyphus* Latreille, 1807**

Sisyphus Latreille, 1807, II: 79; Gory, 1833: 1–15; Lacordaire, 1856, III: 72; Reitter, 1892 (1893): 158, 164; Péringuey, 1900 (1901): 22, 94–103, 897, 898; Arrow, 1927a: 456–465; Arrow, 1931: 67; Balthasar, 1935: 52; Haaf, 1955: 341; Balthasar, 1963, I: 233.

***Sisyphus* (s. str.) *longipes* (Olivier, 1789)**

Sisyphus (s. str.) *longipes* Olivier, 1789, I, 3: 164(*Scarabaeus*); Arrow, 1927a: 457; Arrow, 1931: 71; Haaf, 1955: 347, 355; Balthasar, 1963, I: 239–240.

-*minutus* Fabricius, 1792, I: 70; Gory, 1833: 15.

-*helwigi* Fabricius, 1798: 35.

Distribution: India (Karnataka; Kerala: Nilgiri Hills; Maharashtra; Orissa; Tamil Nadu: Ooty; W. Bengal), Myanmar, Sri Lanka, Thailand.

***Sisyphus* (s. str.) *neglectus* Gory, 1833**

Sisyphus (s. str.) *neglectus* Gory, 1833: 14; Arrow, 1927a: 460; Arrow, 1931: 73; Haaf, 1955: 348, 353; Balthasar, 1963, I: 242–243.

-*denticrus* Faimaire, 1886, (6) VII: 320; Arrow, 1931: 74; Balthasar, 1935: 54; Balthasar, 1963, I: 249.

-*laoticus* Arrow, 1927, (9) XIX: 463.

Distribution: China, India (Karnataka; Kerala: Nelliampathi, Wayanad; Uttaranchal), Myanmar, Thailand.

COPRINI

***Heliocopris* Hope, 1837**

Heliocopris Hope, 1837, I: 23; Burmeister, 1846, 27; Reitter, 1892 (1893): 92; Péringuey, 1900 (1901): 109, 310; Arrow, 1931: 84; Balthasar, 1935: 58; Janssens, 1939; 47; Paulian, 1945: 66.

***Heliocopris bucephalus* (Fabricius, 1775)**

Heliocopris bucephalus Fabricius, 1775, I: 24 (*Copris*); Castelnau, 1840: 76; Arrow, 1931: 43; Balthasar, 1969: 61; Paulian, 1945: 68; Balthasar, 1963, I: 303.

-*cristatus* Degeer, 1778, VII: 636 (*Copris*).

-*tmolus* Fischer, 1822, I: Fig. 2.

Distribution: Bangladesh, India (Bihar; East and Peninsular India; Kerala: Wayanad; Madhya Pradesh; Maharashtra; Tamil Nadu: Hassanur; Tripura; Uttar Pradesh; W. Bengal), Laos, Malay Peninsula, Myanmar, Thailand (Siam), Vietnam.

***Catharsius* Hope, 1837**

Catharsius Hope, 1837, I: 21; Burmeister, 1846, 27; Péringuey, 1900 (1901): 109, 323; Boucomont and Gillet, 1921: 7; Arrow, 1931: 92; Balthasar, 1935: 62; Paulian, 1945: 68; Balthasar, 1963, I: 304.

***Catharsius* (s. str.) *molossus* (Linnaéus, 1758)**

Catharsius (s. str.) *molossus* Linnaéus, 1758, X: 347 (*Scarabaeus*); Harold, 1877, 44; Boucomont and Gillet, 1921: 8; Arrow, 1931: 94; Balthasar, 1935: 65; Paulian, 1945: 69; Balthasar, 1963, I: 307–309.

-*abbreviatus* Herbst, 1789, II: 53.

-*berbiceus* Herbst, I. c.: 227.

-*janus* Olivier, 1789: 101.

-*ursus* Fabricius, 1801, I: 43.

-*borneensis* Paulian, 1936, 15: 396.

-*dubius* Paulian, 1. c.

-*dayacus* Lansberge, 1886, XXIX: 6 .

-*timorensis* Lansberge, 1879, XXII: 148.

-*kangeanus* Paulian, 1. c.: 395 .

Distribution: Afghanistan, Cambodia, China, India (Andaman; Arunachal Pradesh; Assam; Bihar; Gujarath; Hariyana; Karnataka; Kerala: Kinavellore, Nelliampathi, Wayanad; Maharashtra: Mumbai; Meghalaya; Orissa; Rajasthan; Sikkim; Tamil Nadu; Uttaranchal; W. Bengal), Laos, Malay (Sunda Island), Malaysia, Nepal, Sri Lanka, Taiwan, Thailand, Vietnam (Annam).

***Paracopris* Balthasar, 1939**

Paracopris Balthasar, 1939, XXV: 2; Paulian, 1945: 72; Balthasar 1958: 473–474, Balthasar, 1963, I: 329–331.

***Paracopris davisoni*[@] (Waterhouse, 1891)**

Paracopris davisoni[@] Waterhouse, 1891, (6) VII: 520; Arrow, 1931: 132; Balthasar, 1963, I: 373.

Distribution: India (Karnataka; Kerala: Nelliyampathy, Nilgiri hills, Peerumade, Ranipuram, Thekkady, Travancore, Wayanad; Maharashtra: Mumbai; Tamil Nadu: Palni hills).

***Paracopris signatus* (Walker, 1858)**

Paracopris signatus Walker, 1858, (3) 2: 208; Boucomont and Gillet, 1921: 12; Arrow, 1931: 131; Paulian, 1945: 74; Balthasar, 1963, I: 371.

Distribution: India (Karnataka; Kerala: Mahe, Malabar, Thekkady, Travancore, Sendurney, Wayanad; Maharashtra; Tamil Nadu: Coimbatore), Laos, Sri Lanka, Vietnam (Annam).

ONTHOPHAGINI

***Caccobius* Thomson, 1863**

Caccobius Thomson, 1863, V: 34; Harold, 1867, I: 5; Harold, 1867, 1.c. II: 1; Mulsant, 1871: 75; Jekel, 1872: 405; Waterhouse, 1875: 73; Reitter, 1892 (1893): 39, 91; d'Orbigny, 1898; 127; Péringuey, 1900 (1901): 275; Péringuey, 1908: 565; d'Orbigny, 1913: 17; Boucomont and Gillet, 1921: 27; Arrow, 1931: 141; Portevin, 1931: 39; Porta, 1932:

412; Matsumura, 1936: 61; Paulian, 1945: 81; Balthasar, 1949: 1; Balthasar, 1963, II: 113.

-subg. *Caccophilus* Jekel, 1872, 1.c.: 410; d'Orbigny, 1898: 130; d'Orbigny, 1913: 21; Balthasar, 1935e: 183; Balthasar, 1949: 7.

***Caccobius* (*Caccophilus*) *gallinus*[@] Arrow, 1907**

Caccobius (*Caccophilus*) *gallinus*[@] Arrow, 1907, (7) XIX: 424 (*Onthophagus*); Arrow, 1931: 142, 148; Balthasar, 1949: 14, 33; Balthasar, 1963, II: 136-137.

Distribution: India (Kerala: Nelliyampathy, Nilgiri hills, Wayanad)

***Caccobius* (*Caccophilus*) *meridionalis* Boucomont, 1914**

Caccobius (*Caccophilus*) *meridionalis* Boucomont, 1914, VI (XLVI): 239; Arrow, 1931: 142, 148; Balthasar, 1949: 8, 36; Balthasar, 1963, II: 138.

Distribution: India (Karnataka; Kerala: Anaimalai hills, Erumaiyoor, Mahe, Nelliyampathy, Nilgiri hills, Ranipuram, Shendurney, Silent valley, Thekkady, Wayanad; Gujarat; Maharashtra), Sri Lanka.

***Caccobius* (*Caccobius*) *rufipennis*[#@]* (Motschulski, 1858)**

Caccobius (*Caccophilus*) *rufipennis*[#@]* Motschulski, 1858, VII: 53 (*Onthophagus*); Arrow, 1931: 142,158; Balthasar, 1949: 6, 25.

-*rufipennis* Harold (nec Motschulsky) 1867, II: 8.

Distribution: India (Kerala: Chinnar), Sri Lanka.

***Caccobius* (*Caccophilus*) *ultor* Sharp, 1875**

Caccobius (*Caccophilus*) *ultor* Sharp, 1875, xiii: 50; Balthasar, 1963, II: 135.

Distribution: India (Haryana: Kanneri; Karnataka: Budipadaga; Kerala: Nelliampathi, Ranipuram; Maharashtra: Bombay, Khandesh; Punjab; Rajasthan; Uttar Pradesh).

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

Caccobius (*Caccophilus*) *unicornis* Fabricius, 1798: 33 (*Copris*); Boucomont, 1914: 236 (*Onthophagus*); Arrow, 1931: 142, 145; Balthasar, 1933d: 51; Paulian, 1945: 83; Balthasar, 1949: 10, 44; Balthasar, 1963, II: 142-143.

-*nitidiceps* Fairmaire, 1893, XXXVII: 304; Boucomont, 1914: 313, 314; Boucumont and Gillet, 1921: 34, 59.

-*yamauchii* Matsumura, 1936, XI: 66.

Distribution: China, India (Assam; Kerala: Silent valley, Wayanad; Madhya Pradesh; Tripura; W. Bengal), Indonesia (Borneo, Java, Sumatra), Malay Peninsula, Myanmar, Philippines, Sri Lanka, Taiwan.

***Caccobius* (*Caccophilus*) *vulcanus* (Fabricius, 1801)**

Caccobius (*Caccophilus*) *vulcanus* Fabricius, 1801, I: 41 (*Copris*); Harold, 1867, II: 11; Arrow, 1931: 142, 151; Balthasar, 1935e: 195; Balthasar, 1949: 13, 34.

-*bicuspis* Wiedmann, 1823, II 1: 11.

-*mutans* Sharp, 1825, XIII: 51.

Distribution: India (Bihar; Karnataka: Bangalore; Kerala: Erumaiyoor, Ranipuram), Sri Lanka.

***Cleptocaccobius* Cambefort, 1984**

Cleptocaccobius Cambefort, 1984, XI: 3; Cambefort, 1979: 126.

***Cleptocaccobius arrowi* Cambefort, 1985**

Cleptocaccobius arrowi Cambefort, 1985, 7(3): 125, 128, 130.

Distribution: India (Karnataka: Bangalore; Kerala: Malabar, Ranipuram, Shendurney; Maharashtra: Mumbai; Nagpur).

***Onthophagus* Latreille, 1802**

Onthophagus Latreille, 1802, III: 141; Mulsant, 1842: 102; Erichson, 1848. III: 762; Lacordaire, 1856. III: 107; Mulsant-rey, 1871: 78; Reitter, 1892 (1893): 47; d'Oribgny, 1898: 132; d'Oribgny, 1900: 289; Péringuey, 1900 (1901): 168; Péringuey, 1908: 560; Reitter, 1909: 325; Bedel, 1911; 25; d'Oribgny, 1913: 49;1915: 378 (Suppl.); Boucomont, 1914: 238; Boucomont and Gillet, 1921: 1; Boucomont, 1924a: 669; Arrow, 1930: 159; Portevin, 1931:42; Porta, 1932: 408; Balthasar, 1935d: 303; Savcenko, 1938; 46, 136; Paulian, 1941:66; Paulian, 1945: 85; Endrödi, 1956:94; Tesař, 1957: 127; Balthasar, 1963, II: 153.

-*Monapus* Erichson, 1848, III: 763.

-*Psilax* Erichson, 1848, 1.c.

-subg. *Matashia* Matsumura, 1938, XII: 63.

-subg. *Proagoderus* Lansberge, 1883, V: 14; d'Oribgny, 1913: 493; Boucomont, 1914: 261; Marcus, 1917, A (1919): 1; Marcus, 1920: 177; Marcus, 1921: 163; Balthasar, 1963, II: 158.

-*Tauronthophagus* Shipp, 1895, XXVIII: 179.

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

-subg. *Colobonthophagus* Balthasar, 1935, 1.c.: 308; Paulian, 1945, 87; Balthasar, 1963, II: 164.

-subg. *Digitonthophagus* Balthasar, 1959, 1.c.: 464; Balthasar, 1963, II: 159.

-subg. *Paraphanaeomorphus* Balthasar, 1959, 1.c.: 465; Balthasar, 1963, II: 162.

***Onthophagus* (*Paraphanaeomorphus*) *bifasciatus* (Fabricius, 1781)**

Onthophagus (*Paraphanaeomorphus*) *bifasciatus* Fabricius, 1781, I: 25 (*Scarabaeus*); Arrow, 1931; 327, 339; Balthasar, 1963, II: 292–293.

-*birmanicus* Harold, 1879, XVI: 226; Arrow, 1931: 339.

Distribution: India (Assam; Bihar; Kerala: Nilgiri hills, Ranipuram, Thekkady, Wayanad; Sikkim; W. Bengal), Myanmar.

***Onthophagus* (s. str.) *cervus* (Fabricius, 1798)**

Onthophagus (s. str.) *cervus* Fabricius, 1798: 31 (*Copris*); d'Orbigny, 1898: 214; Boucomont, 1914a: 227; Arrow, 1931: 328, 348; Balthasar, 1963, II: 307.

-*nuchidens* Fabricius, 1798, 1. c.: 31.

-*ceylonicus* Harold, 1877, X: 61; Boucomont, 1914a: 225.

Distribution: India (Karnataka; Kerala: Calicut, Nilgiri hills, Ranipuram, Thekkady, Wayanad; Madhya Pradesh; Maharashtra; Tamil Nadu: Coimbatore, Puducherry; Uttaranchal; W. Bengal), Sri Lanka,

***Onthophagus* (s. str.) *dama* (Fabricius, 1798)**

Onthophagus (s. str.) *dama* Fabricius, 1798: 32 (*Copris*); d'Oribgny, 1898: 217; Arrow, 1931: 279, 280; Balthasar, 1963, II: 325–326.

-*aeneus* Olivier, 1789, I(3): 131.

-*zubači* Balthasar, 1932, 93: 151; Arrow, 1933: 422.

Distribution: Bhutan, India (Bihar; Karnataka; Kerala: Nilambur, Nilgiri hills, Ranipuram, Thekkady, Wayanad; Maharashtra; Sikkim; Tamil Nadu: Anaimalai hills; Uttaranchal; W. Bengal), Nepal, Sri Lanka.

***Onthophagus* (*Colobonthophagus*) *ephippioderus* Arrow, 1907**

Onthophagus (*Colobonthophagus*) *ephippioderus* Arrow, 1907, 7(XIX): 425; Arrow, 1931: 279, 290.

Distribution: India (Kerala: Nilgiri hills; Karnataka: Belgaum).

***Onthophagus* (s. str.) *falsus* Gillet, 1925**

Onthophagus (s. str.) *falsus* Gillet, 1925, XLIV: 236; Arrow, 1931: 328, 350; Balthasar, 1963, II: 345-346.

-*cervus* d'Orbigny (nec Fabricius), 1898, XXIX: 214.

Distribution: Afghanistan, Bangladesh, India (Assam; Kashmir; Kerala: Ranipuram, Thekkady, Wayanad; W. Bengal).

***Onthophagus* (s. str.) *fasciatus* Boucomont, 1914**

Onthophagus (s. str.) *fasciatus* Boucomont, 1914, XLVI: 231; Arrow, 1931: 310, 311; Balthasar, 1963, II: 347.

Distribution: India (Karnataka; Kerala: Nilgiri hills, Ranipuram, Thekkady, Wayanad; Madhya Pradesh; Maharashtra: Mumbai; Uttaranchal; W. Bengal; Tamil Nadu: Anaimalai hills, Madhura).

***Onthophagus* (s. str.) *furcillifer* Bates, 1891**

Onthophagus (s. str.) *furcillifer* Bates, 1891, XIV: 11; Arrow, 1931: 270, 273; Balthasar, 1963, II: 360.

Distribution: India (Assam; Kashmir; Kerala: Ranipuram, Thekkady, Wayanad; Punjab; Uttaranchal).

***Onthophagus* (s. str.) *furculus* (Fabricius, 1798)**

Onthophagus (s. str.) *furculus* Fabricius, 1798: 33 (*Copris*); Boucomont, 1914a: 232; Arrow, 1931: 204, 205; Balthasar, 1963, II: 360–362.

Distribution: India (Tamil Nadu: Puthuchery).

***Onthophagus* (s. str.) *ludio* Boucomont, 1914**

Onthophagus (s. str.) *ludio* Boucomont, 1914, XLVI: 218; Arrow, 1931: 328, 346; Balthasar, 1963, II: 422–423.

Distribution: India (Kerala: Nilgiri hills; Maharashtra: Belgaum, Bombay, Nagpur), Sri Lanka.

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

Onthophagus (*Colobonthophagus*) *pardalis* Fabricius, 1798: 29 (*Copris*); Boucomont, 1914, XLVI: 221; Arrow, 1931: 279, 285; Balthasar, 1963, II: 468.

Distribution: India (Kerala: Nilgiri hills; Maharashtra: Bombay; Kanara).

***Onthophagus* (s. str.) *quadridentatus* (Fabricius, 1798)**

Onthophagus (s. str.) *quadridentatus* Fabricius, 1798: 34 (*Copris*); Arrow, 1931: 279, 282; Balthasar, 1963, II-494.

-*quadricornis* Fabricius, 1801, 1: 54; Boucomont, 1914: 305; Boucomont, 1914a: 229.

-*moerens* Walker, 1858, (3) II: 209; Boucomont, 1914; 1.c.

Distribution: India (Assam; Karnataka: Bangalore, Belgaum; Kerala: Chinnar, Mahe, Malabar, Nilgiri Hills, Palakkad; Maharashtra: Bombay, Pune; Tamil Nadu: Coimbatore; W. Bengal: Calcutta), Sri Lanka (Colombo).

***Onthophagus* (s. str.) *spinifex* (Fabricius, 1781)**

Onthophagus spinifex Fabricius, 1781, I: 29 (*Scarabaeus*); Fabricius**,** 1801, I: 49; Boucomont, 1914 a: 222; Arrow, 1931: 185, 200; Balthasar, 1963,II:534.

-*spinifer* Oliver, 1789, I (3): 148 (*Scarabaeus*).

-*aeneus* Fabricius, 1781, i.c.: 34; Harold, 1880, IV: 154.

-*truncaticornis* Herbst, 1789, II: 209; Harold, 1880, 1.c.

-*reflexicornis* Redtenbacher, 1868: 57; Harold, 1872, XI: 206.

-*bifossus* d'orbingny, 1902, LXXI: 145; d'orbingny, 1908, LXXVII: 155.

Distribution: India (Bengal; Bihar; Kerala: Chinnar, Nilgiri Hills; Maharashtra: Bombay; Tamil Nadu: Madura), Sri Lanka (Colombo).

***Onthophagus* (s. str.) *turbatus* Walker, 1858**

Onthophagus (s. str.) *turbatus* Walker, 1858, (3) II: 209; Boucomont, 1914a: 222; Boucomont and Gillet, 1921: 54; Arrow, 1931: 327, 329; Balthasar, 1963, II: 569.

Distribution: India (Karnataka; Kerala: Mahe, Malabar, Nelliampathi, Nilgiri hills; Maharashtra; Tamil Nadu: Puducherry), Sri Lanka.

***Onthophagus* (s. str.) *unifasciatus* Schaller, 1783**

Onthophagus unifasciatus Schaller, 1783, I: 240 (*Scarabaeus*); Fabricius, 1792: 49; Arrow, 1931: 327, 341. Balthasar, 1963, II-571-572.

-*prolixus* Walker, 1858: 208; Harold, 1869, IV: 1038.

Distribution: India (Bengal; Bihar; Kerala: Nilgiri Hills; Maharashtra: Bombay; Tamil Nadu: Coimbatore, Madras), Sri Lanka (Colombo, Kandy).

ONITICELLINI

***Tibiodrepanus* Krikken, 2009**

Tibiodrepanus Krikken, 2009, Haroldius 4: 1–30; Kirby, 1828, III: 521 (*Drepanocerus*); Castelnau, 1840: 92; Lacordaire, 1856, Gen. Col. II: 105, III; Péringuey, 1900 (1901): 108, 110; Boucomont and Gillet 1921: 19; Boucomont, 1921b: 200; Arrow, 1931: 380; Balthasar, 1935: 97; Paulian, 1945: 50, 137; Janssens, 1953: 9. 12; Balthasar, 1963, II: 61.

-*Ixodina* Roth, 1851, XVII (I): 128.

-*Cyptochirus* Lesne, 1900: 499.

-*Drepanochirus* Péringuey, 1900 (1901), XII: 17; Boucomont, 1921b: 199.

***Tibiodrepanus setosus* (Wiedemann, 1823)**

Tibiodrepanus setosus Wiedemann, 1823, II (1): 19 (*Copris*); Arrow, 1931: 381; Janssens, 1953: 19, 31; Balthasar, 1963, II: 68–69 (*Drepanocerus*); Krikken, 2009, Haroldius 4: 1–30.

-*setosa* Motschulsky, 1863, XXXVI (II): 459 (*Ixodina*).

Distribution: India (Kerala: Nelliampathi, Nilgiri hills, Wayanad; Tamil Nadu: Anamalai hills).

***Tibiodrepanus sinicus* (Harold, 1868)**

Tibiodrepanus sinicus Harold, 1868, IV: 104; Arrow, 1931: 381, 383; Balthasar, 1935: 99; Paulian, 1945: 138, 139; Janssens, 1953: 20, 31.

-*setosus* Boheman (nec Wiedmann), 1858: 50; Balthasar, 1963, II: 67–68 (*Drepanocerus*); Krikken, 2009, Haroldius 4: 1–30.

Distribution: India (Central and Northern India; Kerala: Nelliampathi), Laos, Myanmar, North Vietnam, Southern China.

***Tiniocellus* Péringuey, 1900**

Tiniocellus Péringuey, 1900 (1901), XII: 116; Péringuey, 1908, 1.c. XIII: 693; Arrow, 1908: 183; d' Oribgny, 1916, 13: 29; Boucomont, 1923: 53.

***Tiniocellus spinipes* (Roth, 1851)**

Tiniocellus spinipes Roth, 1851, XVII, 1: 128 (*Oniticellus*); Boucomont, 1921: 211; Arrow, 1931: 378 (=*modestus* Arrow); Balthasar, 1935: 102;

Janssens, 1939: 12, 16; Müller G, 1940, II: 97; Balthasar, 1963, II: 108-109.

-*variegatus* Fåhraeus, 1857,II: 320.

-*humilis* Gerstaecker, 1871, XXXVI, 1: 52.

-*imbellis* Bates, 1891, XXVI: 13.

-*setifer* Kraatz, 1895: 143.

Distribution: Angola, Brazil (Natal), Congo, Ethiopia, Guinea, India (Karnataka; Kerala: Calicut, Nilambur, Wayanad; Madhya Pradesh; Maharashtra; Punjab: Chari; Uttaranchal), Malawi, Somalia, South Africa (Transvaal), Tanzania, Uganda, Zimbabwe.

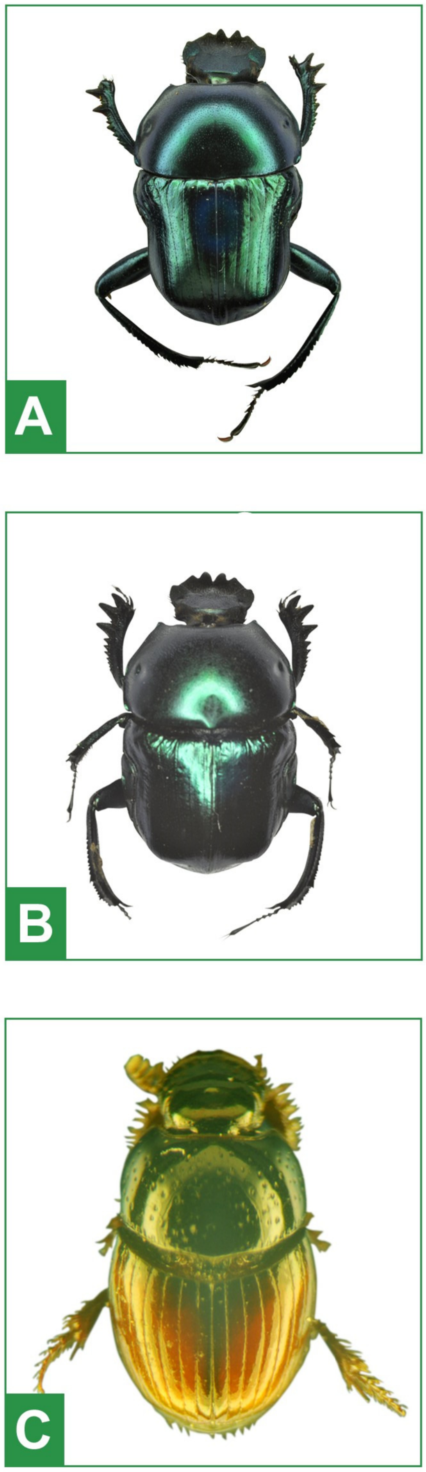


Plate 3: Dung beetle species- (A) *Garreta smaradgifer* male, (B) *Garreta smaradgifer* female and (C) *Caccobius rufipennis*.

Plate 4: Dung beetle species- (D) *Caccobius gallinus,* (E) *Paracopris davisoni* and (F) *Scarabaeus sanctus.*

4.1.2. Pictorial key to the dung beetles of Chinnar region

KEY TO THE TRIBES AND SUBTRIBES OF SUBFAMILY SCARABAEINAE

1(4) Middle coxa not widely separated

2(3) Middle coxa converge strongly behind
- **Scarabaeini**

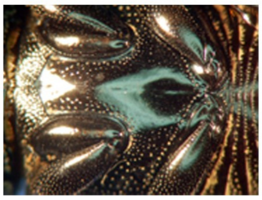
3(2) Middle coxa diagonally placed
- **Gymnopleurini**

4(1) Middle coxa widely separated

5(8) Middle and hind tibiae elongate, slender, not or very little widened towards the apex

6(7) Middle and Posterior tibia elongate
- **Sisyphini**

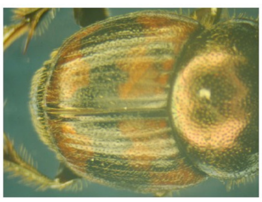
7(6) Middle and Posterior tibia strongly expanded
- **Coprini**



8(5) Middle and hind tibia short, widened towards the apex and triangular

9(10) Body elongate, usually flattened
- **Oniticellini**

10(9) Body usually compact- **Onthophagini**



KEY TO THE GENERA

Scarabaeini

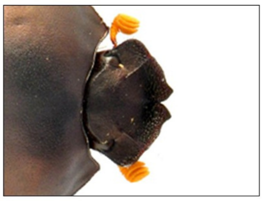
Front tarsi absent- ***Scarabaeus* Linneus**

Gymnopleurini

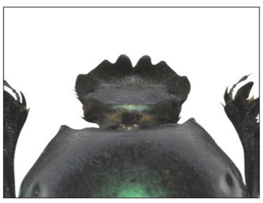
1(2) Median tibia with two apical spurs - ***Paragymnopleurus* Shipp**

2(1) Median tibia with one apical spur

3(4) Clypeus bidentate- ***Gymnopleurus* Illeger**



4(3) Clypeus with 4–6 anterior teeth- ***Garreta* Janssens**



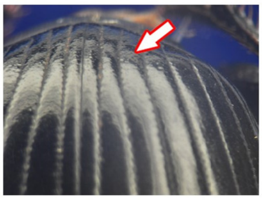
Sisyphini

Body round with disproportionately long legs- ***Sisyphus*** **Latreille**

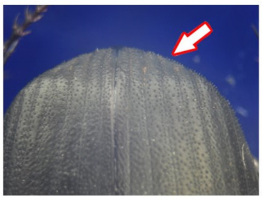
Coprini

1(4) Elytra entirely opaque- ***Catharsius*** **Hope**

2(3) Punctures at the apex and sides of the elytra without hairs- ***Copris*** **Geoffroy**



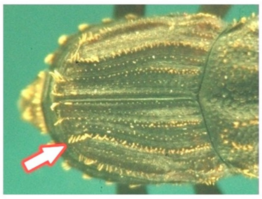
3(2) Punctures at the apex and sides of the elytra bearing short stiff hairs- ***Paracopris*** **Balthasar**



4(1) Elytra shining- ***Heliocopris*** **Hope**

Oniticellini

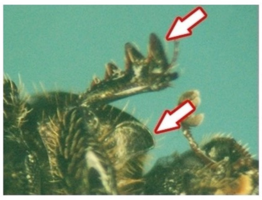
1(2) Elytra fringed before the hind margin
- ***Tibiodrepanus*** **Krikken**



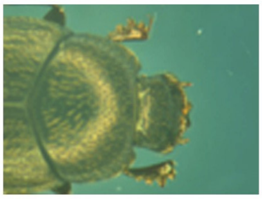
2(1) Elytra fringed only at the hind margin
- ***Tiniocellus*** **Peringuey**

Onthophagini

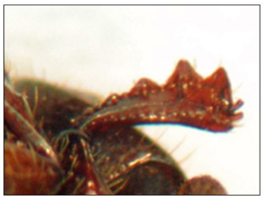
1(4) Terminal margin of the front tibia at right angles to the inner margin and anterior angles of the prothorax hollowed beneath



2(3) Tibia of the male having apical tooth thinned and translucent, in obtuse angle with tibia
- ***Cleptocaccobius*** **Cambefort**



3(2) Tibia of the male having apical tooth not thinned and translucent, in right angle with tibia- ***Caccobius*** **Thomson**



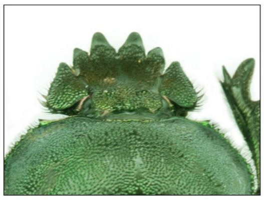
4(1) These characters not both, and usually neither, present- ***Onthophagus*** **Latreille**

KEY TO THE SPECIES

Scarabaeus

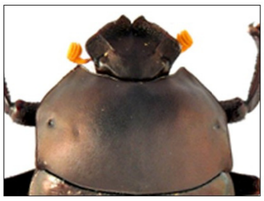
1(2) Clypeal teeth separated by sharp notches
- ***sanctus* Fabricius**

2(1) Clypeal teeth separated by acute notches
- ***erichsoni* Harold**



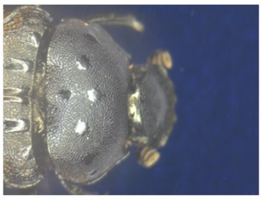
Paragymnopleurus

Pronotum strongly angulate at the sides
- ***sinuatus* (Olivier)**

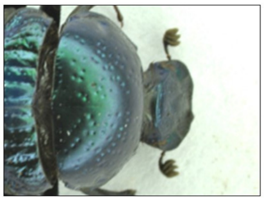


Gymnopleurus

1(2) Pronotum with about six shining spots
- ***parvus* Macleay**

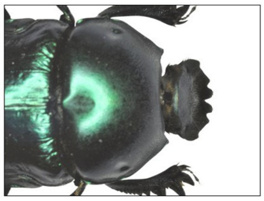


2(1) Pronotum without spots- ***cyaneus* Fabricius**



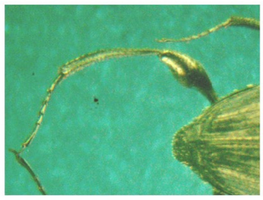
Garreta

Pronotum very smooth- ***smaragdifer*** **Walker**

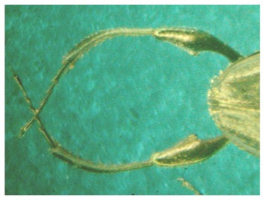


Sisyphus

1(2) Hind femur gradually dilated- ***longipes*** **(Olivier)**

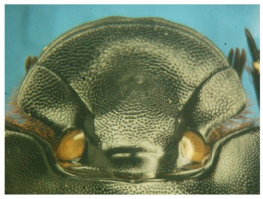


2(1) Hind femur abruptly dilated- ***neglectus*** **Gory**



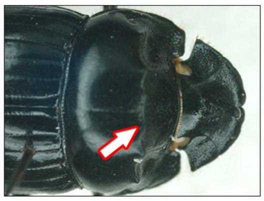
Catharsius

Head with small smooth area adjoining each eye- ***molossus*** **(Linnaéus)**



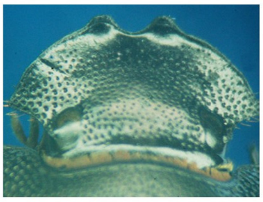
Copris

Pronotum with sharply defined anterior declivity- ***repertus*** **Walker**

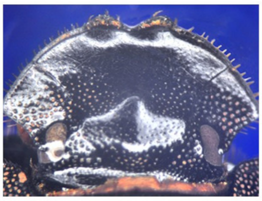


Paracopris

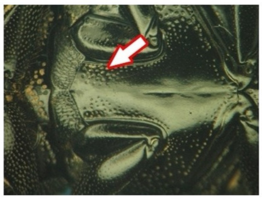
1(2) Clypeus strongly punctured- ***cribratus* Gillet**



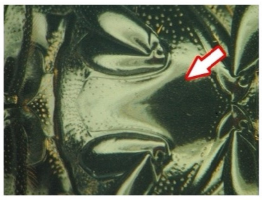
2(1) Clypeus rather smooth



3(4) Metasternal shield punctured in front
- ***davisoni* Waterhouse**



4(3) Metasternal shield not punctured in front
- ***signatus* Walker**



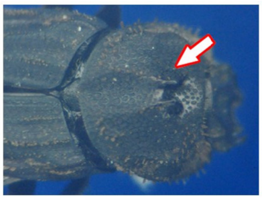
Heliocopris

Single species recorded- ***bucephalus* Fabricius**

Tibiodrepanus

1(2) Male with single thoracic horn- ***setosus* Wiedemann**

2(1) Male with two thoracic horns- ***sinicus* Harold**



Tiniocellus

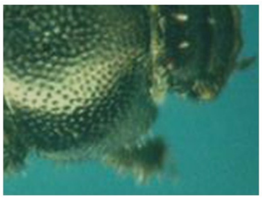
Single species recorded- ***spinipes* Roth**

Cleptocaccobius

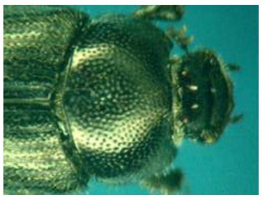
Single species recorded- ***arrowi* Cambefort**

Caccobius

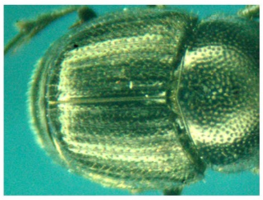
1(8) Pronotum granulate at the sides



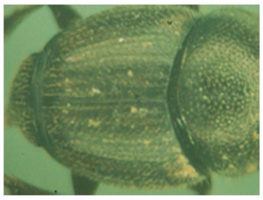
2(7) Pronotum closely punctured



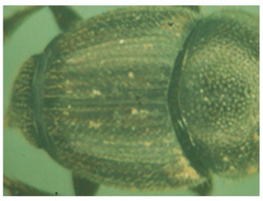
3(4) Elytra very shining- ***gallinus* Arrow**



4(3) Elytra not shining

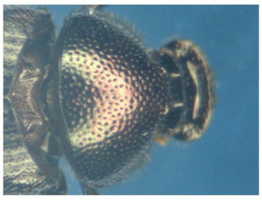


5(6) Elytra entirely black- ***ultor* Sharp**

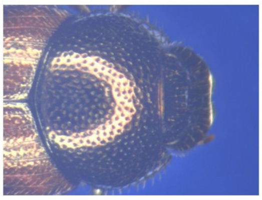


6(5) Elytra brown, variegated- ***meridionalis* Boucomont**

7(2) Pronotum not closely punctured- ***vulcanus* Fabricius**



8(1) Pronotum simply punctured



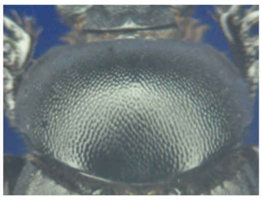
9(10) Upper surface clothed with minute setae - ***unicornis* Fabricius**

10(9) Upper surface devoid of setae- ***rufipennis* Motschulsky**

Onthophagus

1(12) Pronotum wholly or partly or granular or rugose

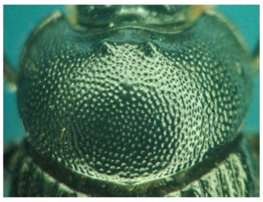
2(5) Pronotum entirely granular or rugose, without distinct punctures



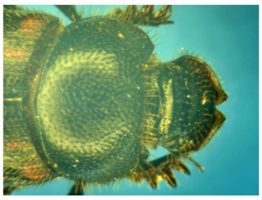
3(4) Upper surface not clothed with dense pile - ***amphinasis*** **Arrow**

4(3) Upper surface clothed with very dense pile - ***tarandus*** **Fabricius**

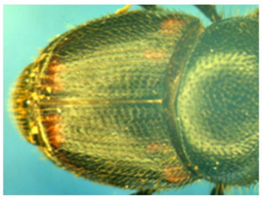
5(2) Pronotum partly granular or rugose, with some punctures



6(9) Pronotum with evenly distributed granules



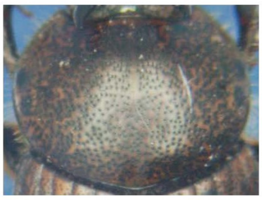
7(8) Elytra not very shining- ***furculus*** **Fabricius**



8(7) Elytra very shining- ***spinifex***

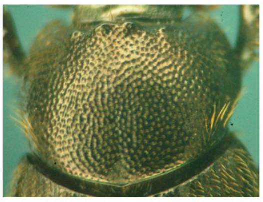
9(6) Pronotum without evenly distributed granules

10(11) Pronotum not shining- ***rectecornutus*** **Lansberge**



11(10) Pronotum shining- ***vividus*** **Arrow**

12(1) Pronotum punctured without granules



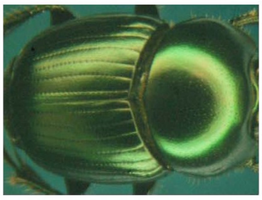
13(20) Upper surface without hair

14(17) Elytral suture with a minute elevation

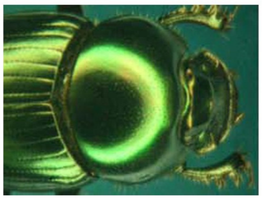
15(16) Head produced in front- ***ephippioderus* Arrow**

16(15) Head not produced in front- ***pardalis* Fabricius**

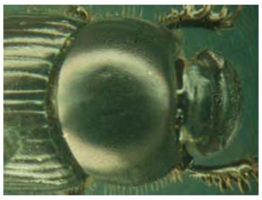
17(14) Elytral suture without a minute elevation



18(19) Pronotum metallic green- ***dama*** **Fabricius**

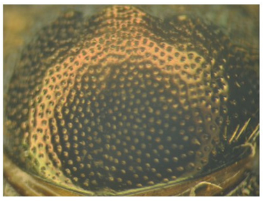


19(18) Pronotum Black- ***quadridentatus*** **Fabricius**

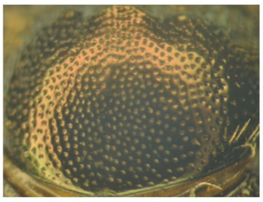


20(13) Upper surface distinctly hairy or setose

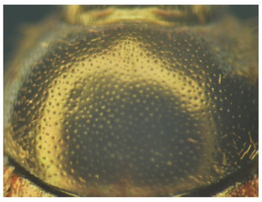
21(26) Pronotum pale at the sides



22(23) Punctures of the pronotum large, close and umbilicate- ***furcillifur* Bates**



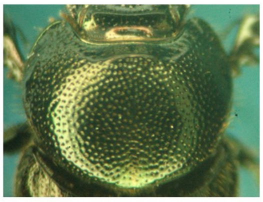
23(22) Punctures of the pronotum not large, close and umbilicate



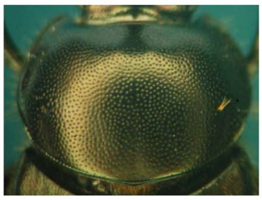
24(25) Elytra with a narrow transverse black band - ***fasciatus* Boucomont**

25(24) Elytra without a narrow transverse black band- ***favrei* Boucomont**

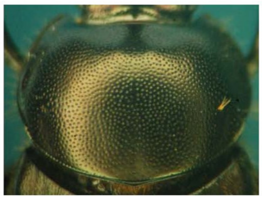
26(21) Pronotum uniformly coloured



27(30) Pronotum finely and closely punctured

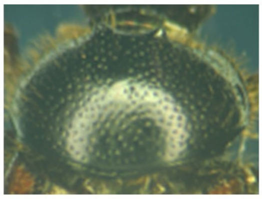


28(29) Pronotum with two thoracic prominence
- ***turbatus*** **Walker**

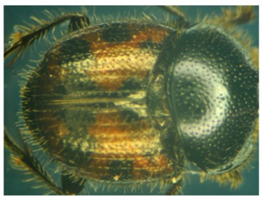


29(28) Pronotum with four thoracic prominence
- ***ensifer*** **Boucomont**

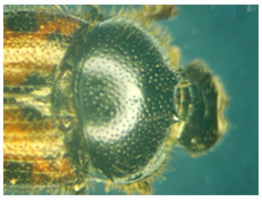
30(27) Pronotum strongly and closely punctured



31(33) Body short and broad



32(35) Pronotum with blunt tubercles anteriorly
- ***ludio*** **Boucomont**



33(31) Body rather elongate

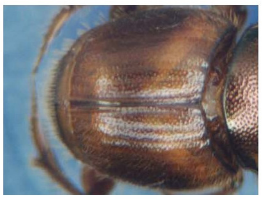
34(38) Elytra without a transverse black band

35(32) Pronotum without blunt tubercles

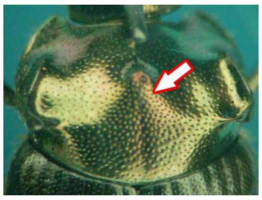
36(37) Pronotum finely and closely punctured
- ***cervus*** **Fabricius**

37(36) Pronotum strongly and closely punctured
- ***falsus*** **Gillet**

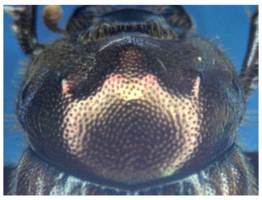
38(34) Elytra with a transverse black band



39(40) Pronotum with a median longitudinal groove
- ***bifasciatus*** **Fabricius**



40(39) Pronotum without a median longitudinal groove- ***unifasciatus*** **Schaller**



4.2. Ecology

4.2.1. Abundance, species richness and diversity

A total of 15,242 beetles belonging to 35 species, 13 genera namely; *Caccobius*, *Catharssius*, *Cleptocaccobius*, *Garreta*, *Gymnopleurus*, *Heliocopris*, *Onthophagus*, *Paracopris*, *Paragymnopleurus*, *Scarabaeus*, *Sisyphus*, *Tibiodrepanus* and *Tiniocellus* and six tribes such as Coprini, Gymnopleurini, Onthophagini, Oniticellini, Scarabaeini and Sisyphini, were recorded from the study site during the study period. List of species and their abundance are given in Table 1.

Paragymnopleurus sinuatus (29.72%) and *Caccobius meridionalis* (17.62%) dominated the assemblage and together constituted 47.34% of the total abundance. Other major species were *Caccobius vulcanus*, *Onthophagus dama*, *O. furcillifer* and *O. turbatus*. Whereas *Caccobius unicornis*, *Catharssius molossus*, *Cleptocaccobius arrowi*, *Gymnopleurus cyaneus*, *Onthophagus furculus*, *O. quadridentatus* and *O. spinifex* are considered as minor species (10.78 % of total abundance). Twenty two species namely; *Caccobius gallinus*, *C. rufipennis*, *C. ultor*, *Garreta smaradgifer*, *Heliocopris bucephalus*, *Onthophagus bifasciatus*, *O. cervus*, *O. ephippiorderus*, *O. falsus*, *O. fasciatus*, *O. ludio*, *O. pardalis*, *O. unifasciatus*, *Paracopris davisoni*, *P. signatus*, *Scarabaeus erichsoni*, *S. sanctus*, *Sisyphus longipes*, *S. neglectus*, *Tibiodrepanus setosus*, *T. sinicus* and *Tiniocellus spinipes* were considered as rare species (5.10% of total abundance) (Table 1). Rank of each species based on relative abundance is represented in Figure 1.

Diversity analysis of dung beetles in the thorny forest was analysed. The Shannon-Weaver diversity index was H'= 2.248, Margalef's richness index was d=6.14, Simpson's dominance index was λ= 0.113 and Simpson's evenness index was 1-λ= 0.844.

4.2.2. Functional guild composition

Dung beetles belonging to all three functional guilds namely; dwellers, rollers and tunnelers were present in the assemblage. Tunnelers were the most abundant functional guild (65.13% of total abundance), rollers were the second most abundant (34.33% of total abundance) and dwellers were the least dominant functional guild (0.54% of the total abundance) (Figure 2).

Tunnelers were the most speciose functional guild with 25 species, where as rollers were with seven species namely; *Garetta smaradgifer*, *Gymnopleurus cyaneus*, *Paragymnopleurus sinuatus*, *Scarabaeus erichsoni*, *S. sanctus*, *Sisyphus longipes* and *S. neglectus*. Dwellers were with only three species namely; *Tibiodrepanus setosus*, *T. sinicus* and *Tiniocellus spinipes* (Table 2).

Caccobius meridionalis, *Onthophagus turbatus* and *Caccobius vulcanus* were the most abundant tunnelers species consist more than 40% of the total abundance. Least abundant tunneler species were *Heliocopris bucephalus*, *Onthophagus ephippiorderus* and *Paracopris davisoni*. Among the rollers; *Paragymnopleurus sinuatus* (29.72% of total abundance) was the most abundnat species where as *Scarabaeus sanctus* was the least abundant.

Tiniocellus spinipes was the most abundant and *Tibiodrepanus sinicus* was the least abundant dweller species reported from the study area (Table 2).

Abundance of functional guild showed significant variation (H= 104.35, DF= 2, P= 0.000). Abundance of tunnelers showed significant variation with rollers (P= 0.000) and dwellers (P= 0.000), where as rollers and dwellers showed no significant variation in abundance (P= 0.000).

4.2.3. Temporal guild composition

Diurnal, nocturnal and generalist guild were present. Abundance was in the order of generalist >nocturnal >diurnal. Generalist guild was the most abundant guild with 16 species (88.13% of total abundance), nocturnal guild comprised of 14 species (11.09% of total abundance) and diurnal of five species (0.80% of total abundance). Dominant generalist species was *Paragymnopleurus sinuatus*, nocturnal species was *Onthophagus dama* and diurnal species was *Onthophagus ludio* (Figure 3).

Generalists were the most speciose temporal guild with 16 species, where as nocturnal guild was with 14 species where as diurnal guild was with only five species namely; *Caccobius rufipennis*, *Onthophagus ludio*, *Scarabaeus sanctus*, *Tibiodrepanus setosus* and *T. sinicus* (Table 3).

Paragymnopleurus sinuatus, *Caccobius meridionalis*, *Onthophagus turbatus* and *Caccobius vulcanus* were the most abundant generalist species consist more than 70% of the total abundance. Least abundant generalist species was *Onthophagus fasciatus*. Among the nocturnal guild species;

Onthophagus dama (5.96% of total abundance) was the most abundnat species where as *Heliocopris bucephalus*, *Onthophagus ephippiorderus* and *Paracopris davisoni* were the least abundant nocturnal species. *Onthophagus ludio* was the most abundant where as *Scarabaeus sanctus* was the least abundant diurnal guild species reported from the study area (Table 3).

Significant variation in abundance of guilds was recorded (H= 109.56, DF= 2, P= 0.000). Generalists showed significant variation in abundance with diurnal (P= 0.000) and nocturnal guilds (P= 0.000), while nocturnal guild showed significant variation only with diurnal guild (P= 0.000).

4.2.4. Seasonality

Twenty five species were present during the summer season where as 34 species were recorded during monsoon season. Among 25 species collected during summer season *Onthophagus furcillifer* and *Caccobius meridionalis* were the most abundant and other prominent species were *Caccobius vulcanus*, *Onthophagus furculus*, *O. turbatus* and *Sisyphus neglectus*. *Garreta smaradgifer*, *Gymnopleurus cyaneus*, *Heliocopris bucephalus*, *Onthophagus cervus*, *O. ephippiorderus*, *O. falsus*, *O. pardalis*, *O. spinifex*, *Paracopris davisoni* and *Paragymnopleurus sinuatus* were not reported in summer season (Figure 4). Among the 34 species collected during monsoon season *Paragymnopleurus sinuatus* was the most abundant species and other major species were *Caccobius meridionalis*, *Onthophagus turbatus*, *Caccobius vulcanus* and *Onthophagus dama*. One species *Scarabaeus sanctus* was reported only during summer season (Figure 5).

Overall seasonality of dung beetle abundance showed significant variations with seasons (H= 44.27, DF= 1, P= 0.000). Comparison of abundance between seasons showed significantly higher abundance during monsoon over summer (P= 0.000).

Among the 35 species collected, 21 species showed significant variation with seasons, 14 species showed no significant variation in abundance with seasons. Among the 21 species only three species namely; *Onthophagus furcillifer*, *O. furculus* and *Sisyphus neglectus* showed higher abundance in summer over monsoon. Eighteen species namely; *Caccobius gallinus*, *C. meridionalis*, *C. unicornis*, *C. vulcanus*, *Catharssius molossus*, *Gymnopleurus cyaneus*, *Onthophagus bifasciatus*, *O. cervus*, *O. dama*, *O. falsus*, *O. quadridentatus*, *O. spinifex*, *O. turbatus*, *O. unifasciatus*, *Paragymnopleurus sinuatus*, *Scarabaeus erichsoni*, *Sisyphus longipes* and *Tibiodrepanus setosus* showed higher abundance in monsoon. Fourteen species namely; *Caccobius rufipennis*, *C. ultor*, *Cleptocaccobius arrowi*, *Garreta smaradgifer*, *Heliocopris bucephalus*, *Onthophagus ephippiorderus*, *O. fasciatus*, *O. ludio*, *O. pardalis*, *Paracopris davisoni*, *P. signatus*, *Scarabaeus sanctus*, *Tibiodrepanus sinicus* and *Tiniocellus spinipes* showed no significant variation in abundance with seasons (Table 4).

4.2.4.1. Seasonality of functional guilds

Tunnelers were the most abundant functional guild in the two seasons. Abundance pattern was in the order of tunnelers >rollers >dwellers in both summer and monsoon seasons.

Tunnelers dominated both during summer and monsoon seasons, with 18 species (92.14% of total abundance) in summer and with 25 species (61.20% of total abundance) in monsoon. Four roller species were present (6.26% of total abundance) in summer and six (38.41% of total abundance) in monsoon. Dwellers were represented by three species in summer (1.60% of total abundance) and in monsoon (0.54% of total abundance) (Figure 6 & 7).

Functional guild abundance showed significant variation with both seasons, in summer (H= 63.61, DF= 2, P= 0.000) and in monsoon (H= 65.48, DF= 2, P= 0.000). In summer, tunnelers showed significant variation in abundance with rollers (P= 0.000) and dwellers (P= 0.000), while rollers showed significant variation with dwellers (P= 0.006). In monsoon, tunnelers (P= 0.000) and rollers (P= 0.000) showed significant variation in abundance with dwellers but no significant variation between tunnelers and rollers (P= 0.5633) in monsoon.

Fifteen tunnelers showed significant variation in seasonality where as ten species showed no significant variation. Five rollers showed significant variation in seasonality where as two species showed no significant variation. Only one dweller showed significant variation in seasonality and the other two species were aseasonal.

Seasonal species showed higher abundance during different seasons. Tunnelers namely; *Caccobius gallinus*, *C. meridionalis*, *C. unicornis*, *C. vulcanus*, Catharssius molossus, *Onthophagus bifasciatus*, *O. cervus*, *O. dama*, *O. dama*, *O. falsus*, *O. quadridentatus*, *O. spinifex*, *O. turbatus* and *O.*

unifasciatus were showed significant abundance in monsoon; *Onthophagus furcillifer* and *O. furculus* were showed significant abundance in summer. Rollers namely; *Gymnopleurus cyaneus*, *Paragymnopleurus sinuatus*, *Scarabaeus erichsoni* and *Sisyphus longipes* were showed significant abundance in monsoon where as *Sisyphus neglectus* were significantly abundant in monsoon. *Tibiodrepanus setosus* was the dweller species that showed higher abundance in monsoon (Table 4).

Caccobius rufipennis, *C. ultor*, *Cleptocaccobius arrowi*, *Heliocopris bucephalus*, *Onthophagus ephippiorderus*, *O. fasciatus*, *O. ludio*, *O. pardalis*, *Paracopris davisoni* and *P. signatus* were the aseasonal tunnelers. *Garreta smaradgifer* and *Scarabaeus sanctus* were the aseasonal rollers where as *Tibiodrepanus sinicus* and *Tiniocellus spinipes* were the aseasonal dwellers (Table 4).

4.2.4.2. Seasonality of temporal guilds

Generalist guild was the most abundant temporal guild in the two seasons. Abundance pattern was in the order of generalist >nocturnal >diurnal in both summer and monsoon seasons.

Generalist dominated both during summer and monsoon seasons with 14 species (96.17% of total abundance) in summer and with 16 species (86.95% of total abundance) in monsoon. Nocturnal guild was represented by 6 species (2.07% of total abundance) in summer and by 14 species (12.40% of total abundance) in monsoon. Diurnal guild was represented by five species (1.76%

of total abundance) during summer and by four species (0.65% of total abundance) in monsoon (Figure 8 & 9).

Abundance of temporal guild showed significant variation in summer (H= 60.92, DF= 2, P= 0.000) and in monsoon seasons (H= 77.81, DF= 2, P= 0.000). In summer, generalists showed significant variation in abundance with diurnal (P= 0.000) and nocturnal guilds (P= 0.000), but no significant variation between diurnal and nocturnal guilds (P= 0.5633). In monsoon generalists showed significant variation in abundance with diurnal (P= 0.000) and nocturnal guilds (P= 0.000), while nocturnal guild showed significant variation with diurnal guild (P= 0.000).

Twenty one species comprising 12 generalists showed significant variation in seasonality where as four species showed no significant variation. Eight nocturnal guild species showed significant variation in seasonality where as six species showed no significant variation. Only one diurnal guild species *Tibiodrepanus setosus* showed significant variation in seasonality and the other four species namely; *Caccobius rufipennis*, *Onthophagus ludio*, *Scarabaeus sanctus* and *Tibiodrepanus sinicus* were showed no significant variation in seasonality.

Caccobius gallinus, *C. meridionalis*, *C. unicornis*, *C. vulcanus*, *Gymnopleurus cyaneus*, *Onthophagus furcillifer*, *O. furculus*, *O. turbatus*, *Paragymnopleurus sinuatus*, *Scarabaeus erichsoni*, *Sisyphus longipes* and *S. neglectus* were the seasonal generalists. *Catharssius molossus*, *Onthophagus bifasciatus*, *O. cervus*, *O. dama*, *O. falsus*, *O. quadridentatus*, *O. spinifex* and

O. *unifasciatus* were the seasonal nocturnal guild species and *Tibiodrepanus setosus* was the seasonal diurnal guild species (Table 4).

Seasonal species showed higher abundance during different seasons. Generalists namely; *Caccobius gallinus*, *C*. *meridionalis*, *C*. *unicornis*, *C*. *vulcanus*, *Gymnopleurus cyaneus*, *Onthophagus turbatus*, *Paragymnopleurus sinuatus*, *Scarabaeus erichsoni* and *Sisyphus longipes* showed significant abundance in monsoon where as *Onthophagus furcillifer*, *O*. *furculus* and *Sisyphus neglectus* showed significant abundance in summer. All the seasonal nocturnal species namely; *Catharssius molossus*, *Onthophagus bifasciatus*, *O*. *cervus*, *O*. *dama*, *O*. *falsus*, *O*. *quadridentatus*, *O*. *spinifex* and *O*. *unifasciatus* showed higher abundance in monsoon. The single seasonal species from the diurnal guild, *Tibiodrepanus setosus* showed higher abundance in monsoon.

Four generalist species namely; *Caccobius ultor*, *Cleptocaccobius arrowi*, *Onthophagus fasciatus* and *Tiniocellus spinipes* were aseasonal. Six nocturnal species namely; *Garreta smaradgifer*, *Heliocopris bucephalus*, *Onthophagus ephippiorderus*, *O*. *pardalis*, *Paracopris davisoni* and *P*. *signatus* were aseasonal and four diurnal species namely; *Caccobius rufipennis*, *Onthophagus ludio*, *Scarabaeus sanctus* and *Tibiodrepanus sinicus* were aseasonal (Table 4).

Table 1: Abundance (mean ± SD and percentage), temporal and functional guild composition of dung beetle assemblage associated with thorny forest at Chinnar during 2009–2012.

No.	Species	Mean ± SD	%	Temporal guild	Functional guild
1	*Caccobius gallinus*	0.22 ± 0.17	0.09	G	T
2	*Caccobius meridionalis*	44.75 ± 17.44	17.62	G	T
3	*Caccobius rufipennis*	0.10 ± 0.10	0.04	Di	T
4	*Caccobius ultor*	1.95 ± 1.48	0.77	G	T
5	*Caccobius unicornis*	5.18 ± 2.87	2.04	G	T
6	*Caccobius vulcanus*	26.45 ± 9.31	10.41	G	T
7	*Catharssius molossus*	4.75 ± 2.47	1.87	N	T
8	*Cleptocaccobius arrowi*	2.53 ± 1.16	1.00	G	T
9	*Garetta smaradgifer*	0.10 ± 0.16	0.04	N	R
10	*Gymnopleurus cyaneus*	5.95 ± 2.44	2.34	G	R
11	*Heliocopris bucephalus*	0.05 ± 0.07	0.02	N	T
12	*Onthophagus bifasciatus*	0.75 ± 0.61	0.30	N	T
13	*Onthophagus cervus*	0.30 ± 0.34	0.12	N	T
14	*Onthophagus dama*	15.15 ± 8.39	5.96	N	T
15	*Onthophagus ephippiorderus*	0.05 ± 0.07	0.02	N	T
16	*Onthophagus falsus*	0.15 ± 0.17	0.06	N	T
17	*Onthophagus fasciatus*	0.13 ± 0.11	0.05	G	T
18	*Onthophagus furcillifer*	17.10 ± 3.68	6.73	G	T
19	*Onthophagus furculus*	3.12 ± 1.36	1.23	G	T
20	*Onthophagus ludio*	1.10 ± 0.83	0.43	Di	T
21	*Onthophagus pardalis*	0.10 ± 0.16	0.04	N	T
22	*Onthophagus quadridentatus*	3.30 ± 2.08	1.30	N	T
23	*Onthophagus spinifex*	2.55 ± 1.67	1.00	N	T
24	*Onthophagus turbatus*	34.75 ± 17.52	13.68	G	T
25	*Onthophagus unifasciatus*	0.60 ± 0.37	0.24	N	T
26	*Paracopris davisoni*	0.05 ± 0.07	0.02	N	T
27	*Paracopris signatus*	0.27 ± 0.15	0.10	N	T
28	*Paragymnopleurus sinuatus*	75.50 ± 47.32	29.72	G	R
29	*Scarabaeus erichsoni*	2.13 ± 1.27	0.84	G	R
30	*Scarabaeus sanctus*	0.02 ± 0.04	0.01	Di	R
31	*Sisyphus longiceps*	1.57 ± 0.87	0.62	G	R
32	*Sisyphus neglectus*	1.95 ± 1.33	0.77	G	R
33	*Tibiodrepanus setosus*	0.45 ± 0.28	0.18	Di	Dw
34	*Tibiodrepanus sinicus*	0.35 ± 0.27	0.14	Di	Dw
35	*Tiniocellus spinipes*	0.57 ± 0.41	0.22	G	Dw

Table 2: Functional guild composition of dung beetles associated with thorny forest at Chinnar during 2009–2012.

No.	Species	Mean ± SD	Percentage	Seasonality
	Tunnelers			
1	*Caccobius meridionalis*	44.75 ± 17.44	17.62	SE
2	*Onthophagus turbatus*	34.75 ± 17.52	13.68	SE
3	*Caccobius vulcanus*	26.45 ± 9.31	10.41	SE
4	*Onthophagus furcillifer*	17.10 ± 3.68	6.73	SE
5	*Onthophagus dama*	15.15 ± 8.39	5.96	SE
6	*Caccobius unicornis*	5.18 ± 2.87	2.04	SE
7	*Catharssius molossus*	4.75 ± 2.47	1.87	SE
8	*Onthophagus quadridentatus*	3.30 ± 2.08	1.30	SE
9	*Onthophagus furculus*	3.12 ± 1.36	1.23	SE
10	*Cleptocaccobius arrowi*	2.53 ± 1.16	1.00	AS
11	*Onthophagus spinifex*	2.55 ± 1.67	1.00	SE
12	*Caccobius ultor*	1.95 ± 1.48	0.77	AS
13	*Onthophagus ludio*	1.10 ± 0.83	0.43	AS
14	*Onthophagus bifasciatus*	0.75 ± 0.61	0.30	SE
15	*Onthophagus unifasciatus*	0.60 ± 0.37	0.24	SE
16	*Onthophagus cervus*	0.30 ± 0.34	0.12	SE
17	*Paracopris signatus*	0.27 ± 0.15	0.10	AS
18	*Caccobius gallinus*	0.22 ± 0.17	0.09	SE
19	*Onthophagus falsus*	0.15 ± 0.17	0.06	SE
20	*Onthophagus fasciatus*	0.13 ± 0.11	0.05	AS
21	*Caccobius rufipennis*	0.10 ± 0.10	0.04	AS
22	*Onthophagus pardalis*	0.10 ± 0.16	0.04	AS
23	*Heliocopris bucephalus*	0.05 ± 0.07	0.02	AS
24	*Onthophagus ephippiorderus*	0.05 ± 0.07	0.02	AS
25	*Paracopris davisoni*	0.05 ± 0.07	0.02	AS
	Total %		**65.13**	
	Rollers			
1	*Paragymnopleurus sinuatus*	75.50 ± 47.32	29.72	SE
2	*Gymnopleurus cyaneus*	5.95 ± 2.44	2.34	SE
3	*Scarabaeus erichsoni*	2.13 ± 1.27	0.84	SE
4	*Sisyphus neglectus*	1.95 ± 1.33	0.77	SE
5	*Sisyphus longiceps*	1.57 ± 0.87	0.62	SE
6	*Garetta smaradgifer*	0.10 ± 0.16	0.04	AS
7	*Scarabaeus sanctus*	0.02 ± 0.04	0.01	AS
	Total %		**34.33**	
	Dwellers			
1	*Tiniocellus spinipes*	0.57 ± 0.41	0.22	AS
2	*Tibiodrepanus setosus*	0.45 ± 0.28	0.18	SE
3	*Tibiodrepanus sinicus*	0.35 ± 0.27	0.14	AS
	Total %		**0.54**	

Table 3: Temporal guild composition of dung beetles associated with thorny forest at Chinnar during 2009–2012.

No.	Species	Mean ± SD	Percentage	Seasonality
	Generalist			
1	*Paragymnopleurus sinuatus*	75.50 ± 47.32	29.72	SE
2	*Caccobius meridionalis*	44.75 ± 17.44	17.62	SE
3	*Onthophagus turbatus*	34.75 ± 17.52	13.68	SE
4	*Caccobius vulcanus*	26.45 ± 9.31	10.41	SE
5	*Onthophagus furcillifer*	17.10 ± 3.68	6.73	SE
6	*Gymnopleurus cyaneus*	5.95 ± 2.44	2.34	SE
7	*Caccobius unicornis*	5.18 ± 2.87	2.04	SE
8	*Onthophagus furculus*	3.12 ± 1.36	1.23	SE
9	*Cleptocaccobius arrowi*	2.53 ± 1.16	1.00	AS
10	*Scarabaeus erichsoni*	2.13 ± 1.27	0.84	SE
11	*Caccobius ultor*	1.95 ± 1.48	0.77	AS
12	*Sisyphus neglectus*	1.95 ± 1.33	0.77	SE
13	*Sisyphus longiceps*	1.57 ± 0.87	0.62	SE
14	*Tiniocellus spinipes*	0.57 ± 0.41	0.22	AS
15	*Caccobius gallinus*	0.22 ± 0.17	0.09	SE
16	*Onthophagus fasciatus*	0.13 ± 0.11	0.05	AS
	Total %		**88.13**	
	Diurnal			
1	*Onthophagus ludio*	1.10 ± 0.83	0.43	AS
2	*Tibiodrepanus setosus*	0.45 ± 0.28	0.18	SE
3	*Tibiodrepanus sinicus*	0.35 ± 0.27	0.14	AS
4	*Caccobius rufipennis*	0.10 ± 0.10	0.04	AS
5	*Scarabaeus sanctus*	0.02 ± 0.04	0.01	AS
	Total %		**0.80**	
	Nocturnal			
1	*Onthophagus dama*	15.15 ± 8.39	5.96	SE
2	*Catharssius molossus*	4.75 ± 2.47	1.87	SE
3	*Onthophagus quadridentatus*	3.30 ± 2.08	1.30	SE
4	*Onthophagus spinifex*	2.55 ± 1.67	1.00	SE
5	*Onthophagus bifasciatus*	0.75 ± 0.61	0.30	SE
6	*Onthophagus unifasciatus*	0.60 ± 0.37	0.24	SE
7	*Onthophagus cervus*	0.30 ± 0.34	0.12	SE
8	*Paracopris signatus*	0.27 ± 0.15	0.10	AS
9	*Onthophagus falsus*	0.15 ± 0.17	0.06	SE
10	*Garreta smaradgifer*	0.10 ± 0.16	0.04	AS
11	*Onthophagus pardalis*	0.10 ± 0.16	0.04	AS
12	*Heliocopris bucephalus*	0.05 ± 0.07	0.02	AS
13	*Onthophagus ephippiorderus*	0.05 ± 0.07	0.02	AS
14	*Paracopris davisoni*	0.05 ± 0.07	0.02	AS
	Total %		**11.09**	

Table 4: Seasonal abundance (mean ± SD) of dung beetle species associated with thorny forest at Chinnar during 2009–2012.

No	**Species**	**Summer**	**Monsoon**	**Wilcoxon-Mann/Whitney Test (P- value)**
		Mean ± SD	**Mean ± SD**	**SU-MO**
1	*Caccobius gallinus*	0.03 ± 0.06	0.40 ± 0.22	0.006
2	*Caccobius meridionalis*	17.30 ± 6.30	72.20 ± 20.14	0.000
3	*Caccobius rufipennis*	0.10 ± 0.10	0.10 ± 0.10	0.989
4	*Caccobius ultor*	1.20 ± 0.75	2.70 ± 1.94	0.857
5	*Caccobius unicornis*	1.07 ± 0.33	9.30 ± 3.57	0.015
6	*Caccobius vulcanus*	6.30 ± 2.53	46.60 ± 8.76	0.000
7	*Catharssius molossus*	0.20 ± 0.18	9.30 ± 2.75	0.000
8	*Cleptocaccobius arrowi*	1.77 ± 0.72	3.30 ± 1.44	0.174
9	*Garetta smaradgifer*	0.00 ± 0.00	0.20 ± 0.22	0.082
10	*Gymnopleurus cyaneus*	0.00 ± 0.00	11.90 ± 2.00	0.000
11	*Heliocopris bucephalus*	0.00 ± 0.00	0.10 ± 0.10	0.081
12	*Onthophagus bifasciatus*	0.10 ± 0.13	1.40 ± 0.80	0.004
13	*Onthophagus cervus*	0.00 ± 0.00	0.60 ± 0.46	0.011
14	*Onthophagus dama*	0.40 ± 0.22	29.90 ± 9.65	0.000
15	*Onthophagus ephippiorderus*	0.00 ± 0.00	0.10 ± 0.10	0.081
16	*Onthophagus falsus*	0.00 ± 0.00	0.30 ± 0.23	0.021
17	*Onthophagus fasciatus*	0.17 ± 0.13	0.10 ± 0.10	0.459
18	*Onthophagus furcillifer*	20.60 ± 3.91	13.60 ± 3.07	0.032
19	*Onthophagus furculus*	4.83 ± 1.65	1.40 ± 0.60	0.007
20	*Onthophagus ludio*	0.30 ± 0.23	1.90 ± 1.10	0.100
21	*Onthophagus pardalis*	0.00 ± 0.00	0.20 ± 0.22	0.082
22	*Onthophagus quadridentatus*	0.20 ± 0.16	6.40 ± 2.56	0.000
23	*Onthophagus spinifex*	0.00 ± 0.00	5.10 ± 2.04	0.000
24	*Onthophagus turbatus*	4.40 ± 2.15	65.10 ± 20.20	0.000
25	*Onthophagus unifasciatus*	0.20 ± 0.16	1.00 ± 0.47	0.005
26	*Paracopris davisoni*	0.00 ± 0.00	0.10 ± 0.10	0.081
27	*Paracopris signatus*	0.23 ± 0.14	0.30 ± 0.16	0.569
28	*Paragymnopleurus sinuatus*	0.00 ± 0.00	151.00 ± 56.96	0.000
29	*Scarabaeus erichsoni*	0.07 ± 0.08	4.20 ± 1.51	0.000
30	*Scarabaeus sanctus*	0.03 ± 0.06	0.00 ± 0.00	0.334
31	*Sisyphus longiceps*	0.13 ± 0.12	3.00 ± 1.03	0.000
32	*Sisyphus neglectus*	3.80 ± 1.68	0.10 ± 0.10	0.000
33	*Tibiodrepanus setosus*	0.20 ± 0.14	0.70 ± 0.35	0.035
34	*Tibiodrepanus sinicus*	0.50 ± 0.32	0.20 ± 0.20	0.077
35	*Tiniocellus spinipes*	0.33 ± 0.35	0.80 ± 0.45	0.114

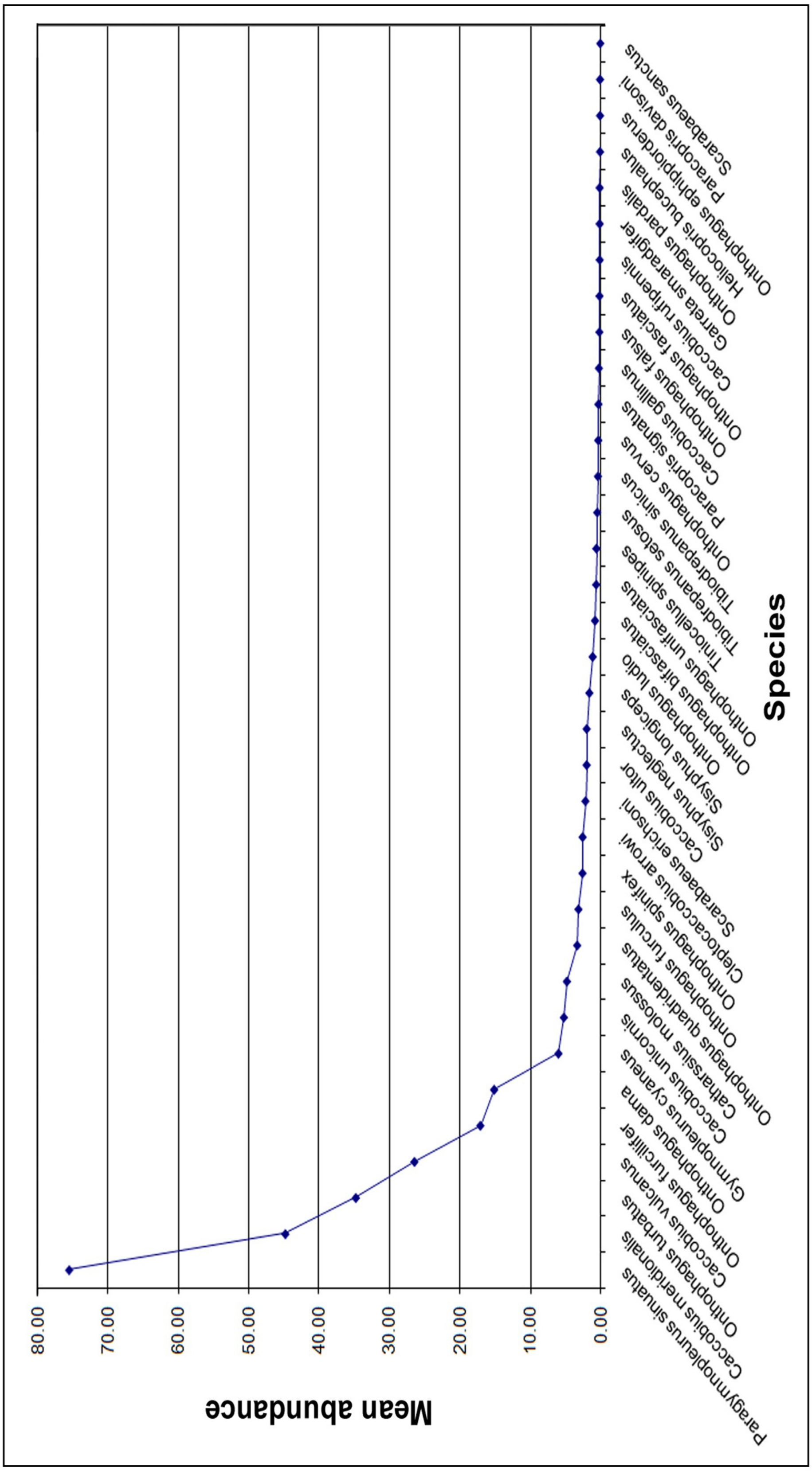


Figure 1: Overall rank abundance plot of dung beetles in a thorny forest habitat at Chinnar.

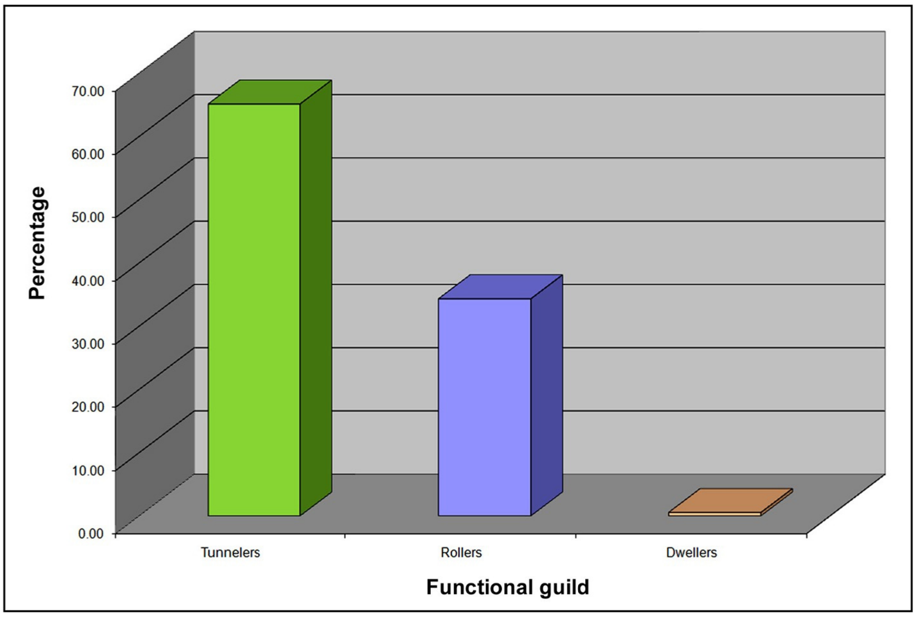


Figure 2: Functional guild abundance of dung beetles in a thorny forest habitat at Chinnar.

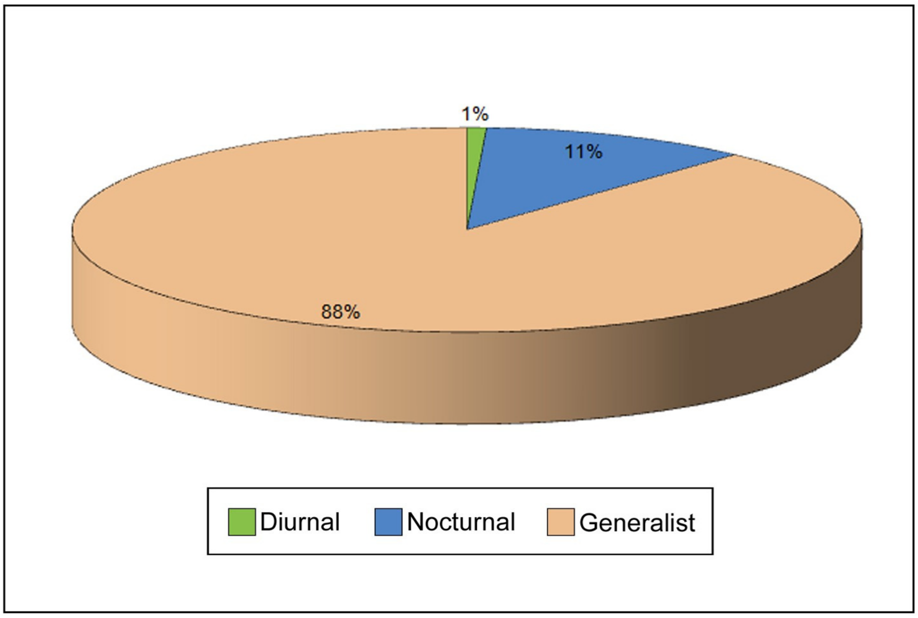


Figure 3: Temporal guild abundance of dung beetles in a thorny forest habitat at Chinnar.

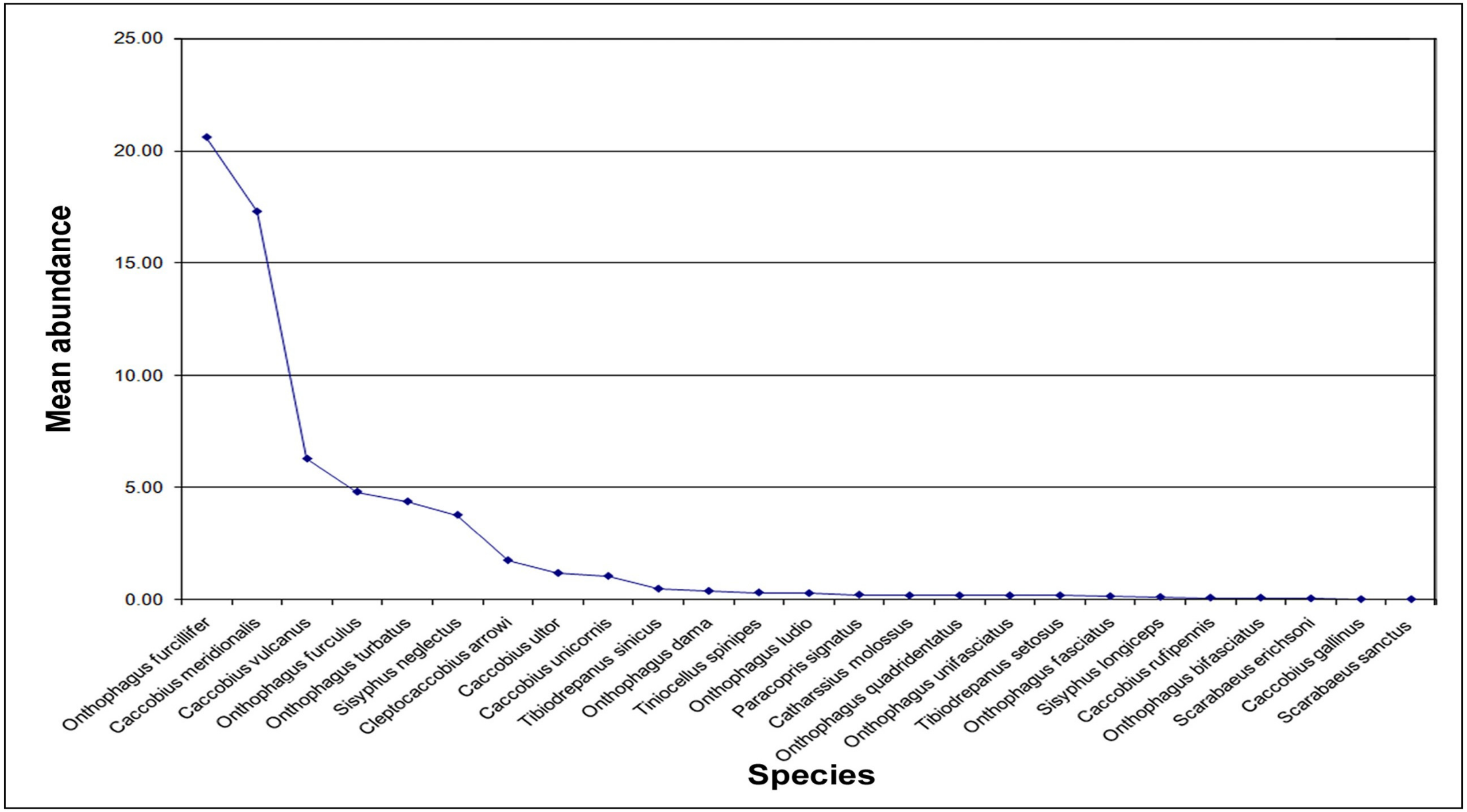


Figure 4: Abundance of dung beetles during summer season in a thorny forests habitat at Chinnar.

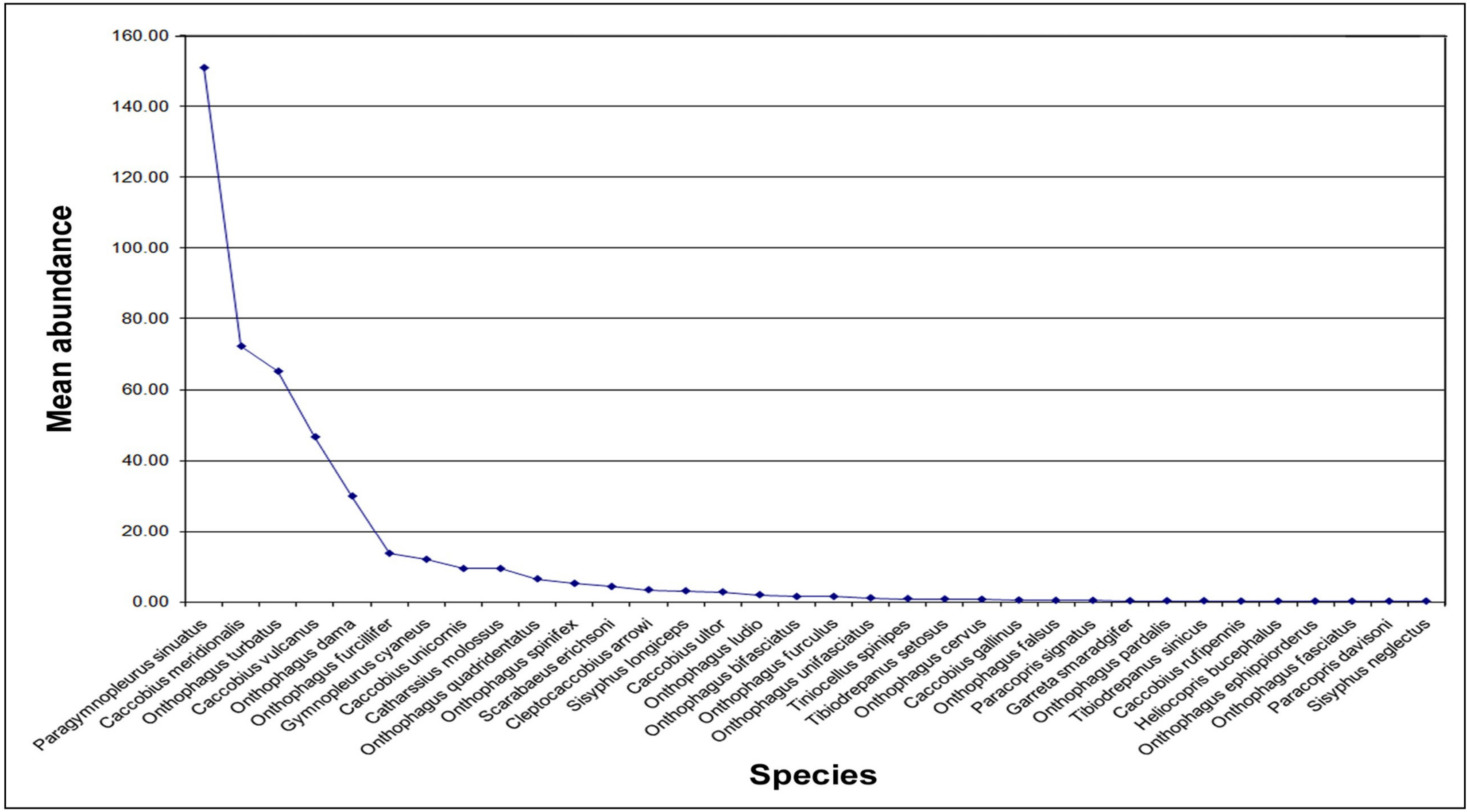


Figure 5: Abundance of dung beetles during monsoon season in a thorny forests habitat at Chinnar.

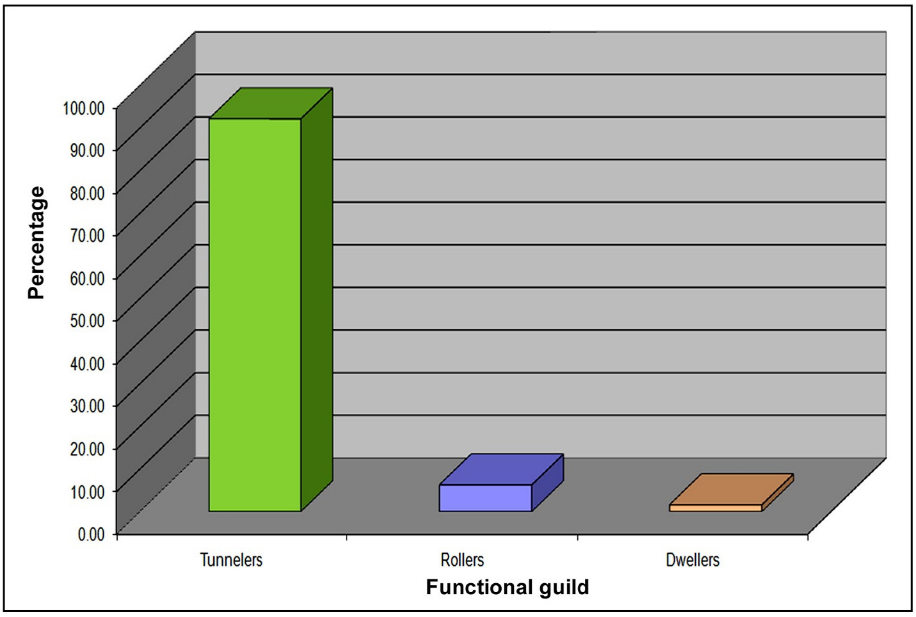


Figure 6: Functional guild abundance of dung beetles during summer season in a thorny forest habitat at Chinnar.

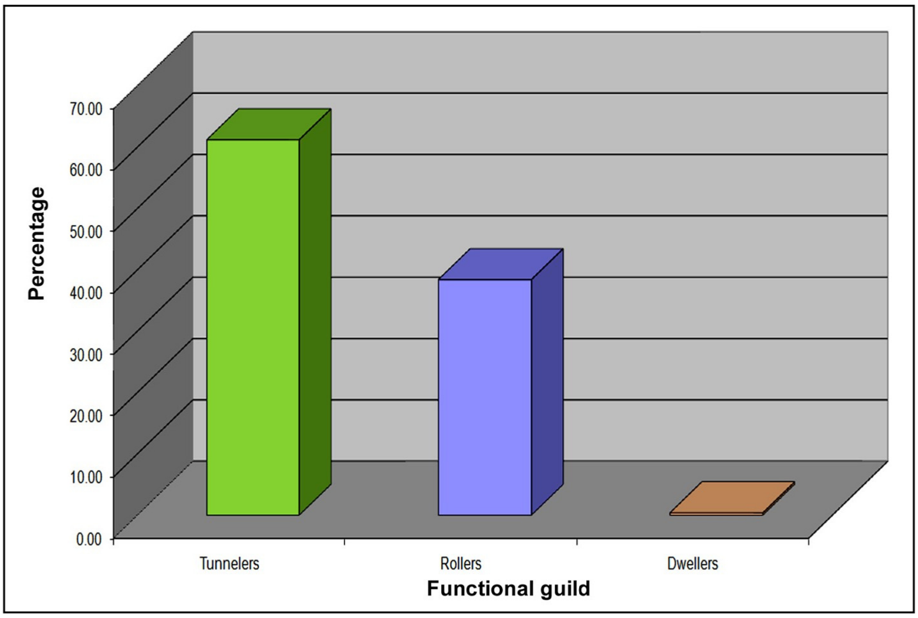


Figure 7: Functional guild abundance of dung beetles during monsoon season in a thorny forest habitat at Chinnar.

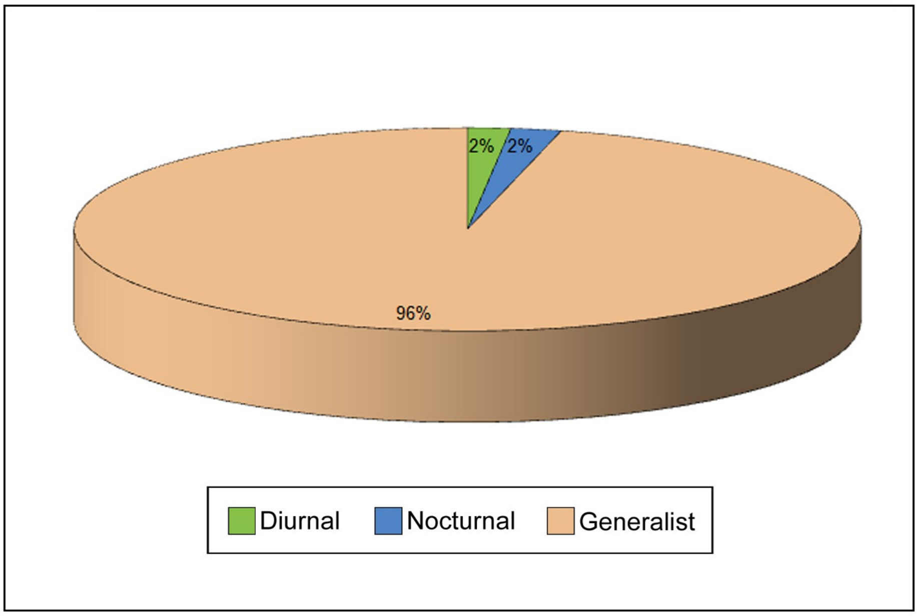


Figure 8: Temporal guild abundance of dung beetles during summer season in a thorny forest habitat at Chinnar.

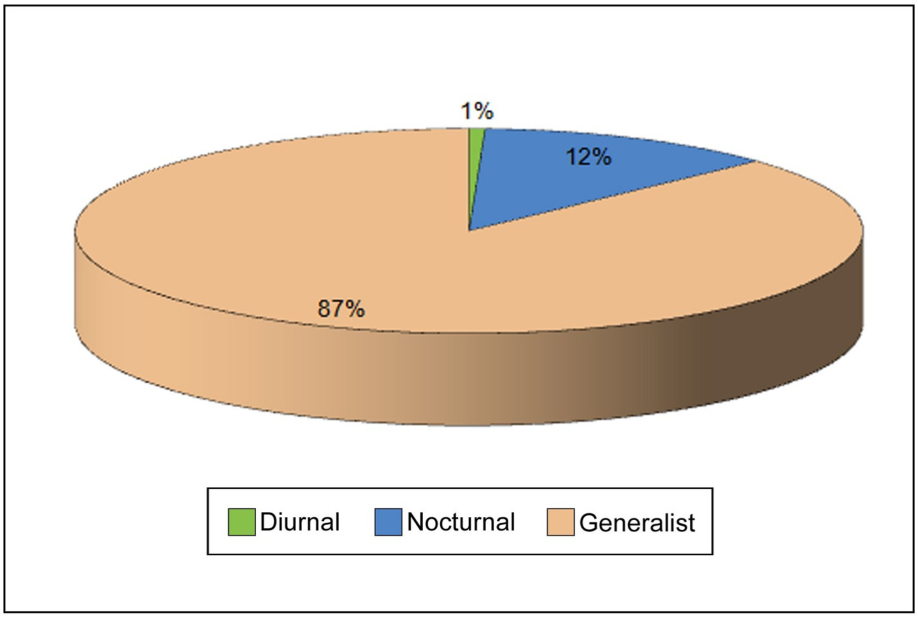


Figure 9: Temporal guild abundance of dung beetles during monsoon season in a thorny forest habitat at Chinnar.

Chapter 5

DISCUSSION

5.1. Taxonomy

Among these 35 species collected, first report of the rare species *Garreta smaragdifer,* which is previously known from Sri Lanka and the first report of the female specimen of the species, is a significant contribution from the Indian subcontinent. *Garreta smaragdifer* was earlier recorded from Sri Lanka with a single specimen in British museum and its female remained unknown (Arrow 1931; Mittal 2011). Male and female specimens differ with respect to the terminal spine of hind tibia which is more curved in female; pronotal and elytral surface with more punctuation in male than in female; clypeal tooth pointed in male and rounded in female and apical spur of the front tibia long and sharp in female and truncate and flat in male. Another significant finding was the first record of rare and endemic species *Caccobius rufipennis* from the Western Ghats which was earlier reported from Sri Lanka (Arrow 1931) and eastern Ghats in India (Priyadarsanan 2006).

Among the eight *Garetta* species known from Indian subcontinent namely; *G. ruficornis* (Motschulsky, 1854), *G. gilletti* (Garreta, 1914), *G. opacus* (Redtenbacker, 1848), *G. dejeani* (Castelnau, 1840), *G. mundus* (Wiedemann, 1819), *G. sumptuosus* (Castelnau, 1840), *G. sylvestris* (Mittal, 2011) and *G. smaragdifer*. *G. dejeani* is endemic to the Western Ghats and *G. smaragdifer* to Sri Lanka (Arrow 1931; Balthasar 1963; Mittal 2011). Present record makes *G. smaragdifer* the second endemic *Garreta* species from the Western Ghats and establishing that it is not a local endemic to Sri Lanka.

Four species endemic to the Western Ghats region was recorded from Chinnar namely; *Caccobius gallinus*, *C. rufipennis*, *Garreta smaragdifer* and *Paracopris davisoni*. Three rare species namely; *Caccobius rufipennis*, *Garreta smaragdifer* and *Scarabaeus sanctus* were recorded from the Chinnar region. Two species of *Scarabaeus* (*S. sanctus* and *S. erichsoni*) recorded from the dry forest region, was not been recorded from the moist south Western Ghats (Sabu *et al.* 2011a). Prevalence of the tribe in the drier leeward eastern slopes of the South Western Ghats and in the dry central Indian plains (Arrow 1931; Balthasar 1963a, b) and non-record from the moist belts of South India indicate that Scarabaeini prefer drier habitats. Four species namely; *Gymnopleurus cyaneus*, *Onthophagus spinifex*, *O. ephippioderus* and *O. pardalis* which are mentioned as extinct species in the checklist of 142 dung beetles of south Western Ghats (Sabu *et al*. 2011a) are present in the dry forest site.

5.2. Ecology

5.2.1. Abundance, species richness and diversity

First time sampling study of dung beetles in a dry forest in the Western Ghats is provided. The assemblage consisted of 35 species which is high when compared with the other dry forests 13–33 species from dry forests in Neotropical region with 15–18 species from Mexico (Andresen 2005, 2008; Halffter & Arellano 2002), 22 species from Columbia (Escobar 1997), 33 species from southern Brazil (Hernández 2005) and 13 species from north eastern Brazil (Liberal *et al*. 2011). Overall, the number of species of dung beetle species in dry forests was lower in tropical rain forests, which often reach over 50 species (Escobar 2000; Feer 2000; Davis *et al*. 2001; Andresen 2002).

Prominent species in Brazilian dry forest were *Canthon latipes* (14.1%), *Onthophagus tristis* (13.6%), *Uroxys* sp. (13.6%) and *Eurysternus francinae* (11.3%), which together represented 52.6% of the total captured individuals (Hernández 2007). In Mexican dry forests the most abundant beetles were *Dichotomius amplicollis* (39%) and *Deltochilum gibbosum* (34%) (Andresen 2005) and were *Deltochilum gibbousm* (14.5%), *Dichotomius amplicollis* (10.5%) and *Onthophagus landolti* (2.50%) in another study (Andresen 2008). *Paragymnopleurus sinuatus* (29.72%) and *Caccobius meridionalis* (17.62%) dominated the assemblage and together constituted 47.34% of the total abundance in Chinnar region. In Neotropical dry forests, species belonging to the tribes Deltochilini, Coprini, Ateuchini and Onthophagini dominated and in Chinnar area two tribes Gymnopleurini and Coprini dominated. This data indicates that the tribe Coprini is common in dry forests in both the regions but with an entirely different species composition as Coprini in Neotropical region is represented by *Dichotomius amplicollis* and *Caccobius meridionalis* in Chinnar region.

Higher abundance of the large roller *Paragymnopleurus sinuatus* which is present with lower abundance in wet forests is attributed to its attraction towards omnivorous boar dung (Sabu 2012) easily available in Chinnar and the dry conditions which make dung rolling easier. Exact reason for the dominance of *Caccobius meridionalis* in the dry forest is unknown. *Caccobius* *meridionalis* is a well adapted species capable of surviving in a variety of habitats and may produce several broods per year as common in small tunnelers (Cambefort & Hanski 1991) and is a dominant species in the wet forests of the south Western Ghats as well.

Knowledge of the species and studies on the ecological and behavioral characteristics of each species is the first steps in finding species indicators to assess the conservation status of a particular ecosystem (Brown 1997). *Caccobius rufipennis*, *Garetta smaradgifer*, *Onthophagus furculus*, *O. spinifex*, *O. unifasciatus*, *Scarabaeus erichsoni* and *S. sanctus* which were not reported from the wet forests of Western Ghats and present in considerable abundance are considered as the dry forest habitat indicators. Species like *Caccobius unicornis*, *C. vulcanus*, *Gymnopleurus cyaneus* and *Paragymnopleurus sinuatus* with high abundance in dry forests and with low abundance in wet forests (Vinod 2009; Latha 2011; Nithya 2012; Sabu 2012) can also be considered as habitat indicators of dry forest.

5.2.2. Functional guild composition

Functional guild composition of the assemblage in the dry forest was not much different from the assemblage in the wet forests of Western Ghats (Sabu *et al*. 2011a) with the dominance of tunnelers (Sabu 2012). However, species composition was different with the dominance of *Onthophagus pacificus*, *Caccobius gallinus* in wet forests and *Onthophagus furcillifer* and *Caccobius meridionalis* in dry forests. Present study indicates that high abundance of tunnelers is typical of dung beetle assemblages in the wet and dry forests of the

Western Ghats (Sabu *et al*. 2006, 2007; Vinod & Sabu 2007; Sabu *et al*. 2011a).

Greater species richness and abundance of tunnelers species compared to the other functional groups was common in the Neotropical dry forests (Halffter *et al.* 1992; Loozada & Lopes 1997; Peck & Howden 1984; Estrada & Coates-Estrada 1991; Hanski & Cambefort 1991b; Andresen 1999). Dominant tunneler in Mexican forests was *Dichotomius amplicollis* (Andresen 2005) *Uroxys* sp. in Brazilian forest (Hernández 2007) and *Caccobious meridionalis* in Chinnar.

Followed by tunnelers (65.13% of total abundance), rollers (34.33% of total abundance) were the second most abundant temporal guild in the dry forest in Western Ghats. Higher abundance of rollers than in moist forests of Western Ghats is arising from the dry conditions which makes dung rolling easier (Sabu 2012) and higher abundance of boar in the region and its dung with the strong odour and the high nutritive quality of omnivorous boar dung (Tshikae *et al.* 2008). Rollers were represented by the large roller species *Paragymnopleurus sinuatus* and smaller species *Scarabaeus sanctus*. Rollers in wet forests were represented by the large rollers species *Sisyphus neglectus* and smaller species by *Paragymnopleurus sinuatus*. Higher abundance of roller guild is arising from the higher abundance of *Paragymnopleurus sinuatus*. It is contrary to the dominance of *Sisyphus* species in the wet forests of Nelliampathi, Wayanad (Vinod & Sabu 2007; Vinod 2009; Sabu 2012) and Thekkady (Nithya 2012) of South Western Ghats. Percentage abundance of rollers in the various forests in the wet south Western Ghats was Thirunelly- 3.19% (Vinod 2009), Thekkady- 3.30% (Nithya 2012) and Ranipuram- 1% (unpublished data). Higher abundance of the genus *Paragymnopleurus* in the dry forests and their lower abundance in the moist forests of the south Western Ghats indicate its adaptation to the vegetation, trophic resource and microclimate of the region.

Rollers were the most abundant functional guild in Neotropical forests (Andresen 2005; Hernández 2007) which is entirely different from the scenario in the present work. Dominant roller species in Neotropical region was *Deltochilum gibbosum* (Andresen 2005) and *Canthon latipes* with an overall abundance of 21.83% (Hernández 2007).

Dweller guild was represented by three rare species, *Tibiodrepanus setosus*, *T. sinicus* and *Tiniocellus spinipes* with low abundance. Similar results were obtained from Thekkady with 5.26% of total abundance (Nithya 2012), 19.51% of the total abundance from Wayanad (Vinod 2009), 3.50% of total abundance from Nelliyampathy (Latha 2011) and there was no record of dwellers from Ranipuram (unpublished data). Very low abundance of dwellers (0.54%) in the present study is contradictory to the results obtained from the forests of Wayanad where they were the second most dominant guild (19.51% of the total abundance) after the tunnelers (Vinod 2009).

Dwellers are strongly associated with larger herbivore dung pads and breed successfully only in undisturbed dung pads with little competition from competitively superior tunnelers and rollers and their abundance is due to the availability of dung pads (Hanski & Cambefort 1991c; Krell *et al*. 2003; Krell-Westerwalbesloh *et al*. 2004). Lowest abundance of dwellers could be due to this competitive removal by other guilds and non availability of undisturbed dung pads in dry forest area.

5.2.3. Temporal guild composition

Abundance pattern of the temporal guild in the wet forests was different from that in the dry forest with generalists as the least abundant temporal guild in wet forests (Vinod 2009; Latha 2011; Nithya 2012) whereas in dry forest, generalists (88.13% of total abundance represented by tunneler, rollers and dwellers) was most abundant, indicating that the foraging time of dung beetles are affected by the rainfall mediated moisture (Hanski & Cambefort 1991a). Dawn and dusk are two periods when the defecation rate of mammals might be expected to peak due to change in activity in both diurnal and nocturnal mammal species (Gill 1991; Hanski & Cambefort 1991a). Generalist nature of dung beetles and their abundance may be a mechanism to avoid competition between species.

Higher frequency of nocturnal individuals were observed in the semideciduous and deciduous forests in Mexico with the dominan species *Deltochilum gibbosum* and *Dichotomius amplicollis* (Andresen 2005) were as nocturnal beetles were the second most abundant temporal guild (11.09% of total abundance) in the dry forest in the study region which is attributed to the positive correlation of paracoprids with the temperature of faeces, soil and air during their activity that peaks at dusk. Species of nocturnal guild are sensitive to the high diurnal temperature and they have thermoregulatory constraints leading to their presence during night.

Diurnal beetles were smaller than nocturnal and generalist species and were the least abundant temporal guild in dry forest. Their diurnal presence in hot dry study region indicates their capacity to withstand the high temperature and their diurnal presence might be enabling them to avoid competition with the dominant generalists and nocturnal species. Smaller size is a widespread trend in dung beetles (Cambefort 1991) and is partially related to thermoregulatory constraints of dung beetles (Bartholomew & Heinrich 1978). Present study showed that all the larger beetles were nocturnal and they might be avoiding high diurnal temperature which may lead to lethal body temperature particularly in large black beetles flying in sun at mid day (Krell *et al*. 2004).

5.2.4. Seasonality

Overall abundance of dung beetles peaked during the beginning of the wet season. Similar pattern of high abundance during the wet season has been reported from the dry forests at *Caatinga*- in Brazil (Hernández 2005, 2007), semiarid environments in Mexico (Andresen 2005). Present finding from the dry forests in the Western Ghats are in full agreement with the reports that, many dung beetle species experience a peak of emerging adults at the beginning of the rainy period (Cambefort & Hanski 1991; Andresen 2005), particularly in dry tropical regions, which are highly influenced by rainfall (Halffter & Mathews 1966; Hanski & Cambefort 1991a).

Significant seasonal effect on abundance was noticed in the dung beetle population with monsoon over summer. It is attributed to the high dung resource availability during wet period in the dry habitat linked to the presence of large population of herbivorous mammals (Kerala forests and Wildlife Department Management Plan 2002-2011). The severity of the dry season which limits the activity of dung beetles to prevent the construction of galleries in the soil due to compaction of the same hardness (Janzen 1983) could be another reason for the significant abundance of dung beetles in monsoon. Further, seasonal activity of dung beetles at a site depends on the temperature and precipitation cycles (Lumaret & Kirk 1991). Interpretation of seasonality in the dry forests with very short rainy season and long dry conditions (Kerala Forests and Wildlife Department Management Plan 2002–2011) is difficult.

Lack of seasonality of three species (*Paragymnopleurus sinuatus*, *Caccobius meridionalis* and *Onthophagus dama*) is attributed to the high incidence with exceptionally high abundance in wet season. Exceptionally high abundance of *Paragymnopleurus sinuatus* indicates that this large roller has a unique attraction towards boar dung.

Onthophagus furcillifer, *O. furculus* and *Sisyphus neglectus* showed higher abundance in summer indicating that these are dry environment adapted species in the region. *Caccobius gallinus*, *C. meridionalis*, *C. unicornis*, *C. vulcanus*, *Catharsius molossus*, *Gymnopleurus cyaneus*, *Onthophagus bifasciatus*, *O. cervus*, *O. dama*, *O. falsus*, *O. quadridentatus*, *O. spinifex*, *O. turbatus*, *O. unifasciatus*, *Paragymnopleurus sinuatus*, *Scarabaeus erichsoni*, *Sisyphus longipes* and *Tibiodrepanus setosus* which showed higher abundance in monsoon. Species which showed significance abundance during monsoon season depends on the optimum conditions prevailing during the short period of rainy season and low rainfall in Chinnar region (Kerala Forests and Wildlife Department Management Plan 2002-2011). The seasonal activity of dung beetles at a site depends on the temperature and precipitation cycles (Lumaret & Kirk 1991). Interpretation of seasonality of dung beetles in the dry forests with very short rainy season lasting 3–4 weeks and long dry conditions (Kerala Forests and Wildlife Department 2004) is difficult until more data on the biology of Indian dung beetles becomes available.

Chapter 6

CONCLUSIONS

First time data of taxonomy and ecology of dung beetles in a thorny forest in the Chinnar region of dry south Western Ghats were studied. A check list and pictorial key of the dung beetle fauna of the region is also provided.

Checklist of dung beetle fauna from Chinnar region of Western Ghats reveals the presence of 35 species, comprising 13 genera and 6 tribes. First report of *Garreta smaragdifer* recorded from the Indian Subcontinent reveals that similar studies in other dry forests in the Western Ghats might disclose new additions to the species lists for the South Indian region. Another significant finding was the first record of rare and endemic species *Caccobius rufipennis* from the Western Ghats. *Caccobius gallinus*, *C. rufipennis*, *Garreta smaragdifer* and *Paracopris davisoni* are endemic to the Western Ghats recorded from the Chinnar region.

Present study found two species namely, *Scarabaeus sanctus* and *S. erichsoni* which is recorded only from the dry forest region and was not been recorded from the moist south Western Ghats. This dominance of the genus in the drier leeward eastern slopes of the south Western Ghats and in the dry central Indian plains and non-record from the moist belts of South India indicate that Scarabaeini prefer drier habitats.

Present study revealed the presence of four species (*Gymnopleurus cyaneus*, *Onthophagus spinifex*, *O. ephippioderus* and *O. pardalis*) which was mentioned as lost species from the south Western Ghats. Presence of these four species from the dry forest of south Western Ghats leads to the conclusion that further studies must be done in the dry forests of south India and that may lead to the unearthing of more rare species from previously unexplored regions.

First time data on the community dynamics of dung beetles in a dry forest in the Western Ghats is provided. Number of species of dung beetles found in dry forest localities is much lower than the one reported for tropical rain forests. *Paragymnopleurus sinuatus* and *Caccobius meridionalis* dominated the assemblage in Chinnar region. It leads to the conclusion that tribe Coprini is common in dry forests with a high abundance but with an entirely different species composition.

Functional guild composition of the assemblage in the dry forest is similar to the assemblage in the wet forests of Western Ghats. The functional guild assemblage is characterized by the dominance of tunnelers proceeded by rollers and dwellers being the least abundant guild. Present study indicates that high abundance of tunnelers is typical of dung beetle assemblages in the wet and dry forests of the Western Ghats.

Higher abundance of rollers in the dry forests than in the moist forests of Western Ghats is due to the dry conditions which makes dung rolling an easier task and also due to the higher abundance of boar and its odoriferous dung with high nutritive quality.

Dwellers are strongly associated with larger herbivore dung pads and breed successfully only in undisturbed dung pads with little competition from competitively superior tunnelers and rollers. Low abundance of dwellers could be due to the competitive removal of fresh dung by other guilds and quick drying up of dung pads in the dry forest area.

Generalist guild dominated because these species are active during day and night and they utilise the maximum resource and are represented by tunnelers, rollers and dwellers. Nocturnal beetles were the second most abundant temporal guild in dry forest. This may be due to the positive correlation of paracoprids with the temperature of faeces, soil and air during their activity peaks at dusk, but a negative correlation with all the temperature parameters during their diurnal peak. They seem to avoid high temperature which must be lethal to the large black beetles.

Assemblage exhibited distinct seasonality with high diversity during the monsoon seasons. The highest abundance values were found at the beginning of the wet season. Many dung beetle species experience a peak of emerging adults at the beginning of the rainy period, the seasonal activity of dung beetles at a site depends on the temperature and precipitation cycles.

The severity of the dry season that limits the construction of galleries in the soil due to compaction could be the reason for the significant abundance of dung beetles during monsoon.

Chapter 7

REFERENCES

Anderson A.B. 1990. Deforestation in Amazonia: dynamics, causes, and alternatives. In: Anderson A.B., editor. *Alternatives to deforestation: steps toward sustainable use of the Amazon rain forest*, 3–23. Columbia University Press, New York.

Andresen E. 1999. Seed dispersal by monkeys and the fate of dispersed seeds in a Peruvian rain forest. *Biotropica*, 31(1): 145–158.

Andresen E. 2000. *The role of dung beetles in the regeneration of rain forests plants in central Amazonia*. Ph.D. Thesis, University of Florida.

Andresen E. 2001. Effect of dung presence, dung amount, and secondary dispersal by dung beetles on the fate of *Micropholis guyanensis* (Sapotaceae) seeds in central Amazonia. *Journal of Tropical Ecology*, 17: 61–78.

Andresen E. 2002. Dung beetles in a Central Amazonian rainforest and their ecological role as secondary seed dispersers. *Ecological Entomology,* 27: 257–270.

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

Andresen E. 2005. Effects of season and vegetation type on community organization of dung beetles in a tropical dry forest. *Biotropica*, 37: 291–300.

Andresen E. 2007. Dung beetle assemblages in primary forest and disturbed habitats in a tropical dry forest landscape in western Mexico. *Journal of Insect Conservation*, 1–12.

Andresen E. 2008. Short-term temporal variability in the abundance of tropical dung beetles. *Insect Conservation and Diversity*, 1: 120–124.

Andresen E. & Laurance S. 2007. Possible indirect effects of mammal hunting on dung beetle assemblages in Panama. *Biotropica*, 39: 141–146.

Andresen E. & Levey D.J. 2004. Effects of dung and seed size on secondary dispersal, seed predation, and seedling establishment of rain forest trees. *Oecologia*, 139: 145–154.

Anduaga S. 2004. Impact of the activity of dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae) inhabiting pasture land in Durango, Mexico. *Environmental Entomol*ogy, 33(5): 1306–1312.

Anu A. 2006. *Entomofaunal dynamics and biochemistry of litter decomposition in an evergreen forest with special reference to systematics of dung beetles* (*Coleoptera: Scarabaeinae*). Ph D. Thesis, University of Calicut.

Arellano L., Leon-Cortes J.L. & Halffter G. 2008. Response of dung beetle assemblages to landscape structure in remnant natural and modified habitats in southern Mexico. *Insect Conservation and Diversity*, 1(4): 253–262.

Arellano L. & Halffter G. 2003. Gamma diversity: derived from and a determinant of alpha diversity and beta diversity, an analysis of three tropical landscapes. *Acta Zoologica Mexicana*, 90: 27–76.

Arellano L., Favila M.E. & Huerta C. 2005. Diversity of dung and carrion beetles in a disturbed Mexican tropical montane cloud forest and on shade coffee plantations. *Biodiversity Conservation*, 14: 601–615.

Arrow G.J. 1907. Some new species and genera of *Lamellicorn* Coleoptera from the Indian empire (part 2). *The Annals and Magazine of Natural History, London*, (7)19: 416–439.

Arrow G.J. 1931. *The fauna of British India including Ceylon and Burma, Coleoptera: Lamellicornia (Coprinae)*. Taylor and Francis. London.

Avendano-Mendoza C., Moron-Rios A., Cano E.B. & Leon-Cortes J. 2005. Dung beetle community (Coleoptera: Scarabaeidae: Scarabaeinae) in a tropical landscape at the Lachua Region, Guatemala. *Biodiversity Conservation*, 14: 801–822.

Balthasar V. 1939. *Monographie der gattung Trichillum Har. Vestnik Ceskoslovenské Spolecnosti Zoologické*, 6–7: 11–26.

Balthasar V. 1955. Scarabaeidae der Afghanistan- expedition (1952–53). J. Klapperichs. *Acta Entomologica Musei Nationalis Pragae*, 30: 409–439.

Balthasar V. 1959. Beitrag zur kenntnis der gattung *Onthophagus* Latreille. *Acta Entomologica Musei Nationalis Pragae*, 33: 461–471.

Balthasar V. 1963a. *Monographic der Scarabaeidae und Aphodiidae der Palaearktischen und Orientalischen Region (Coleoptera: Lamellicornia)*, Volume 1, Verlag der Tschechoslowakischen Akademie der Wissenschaften. Prag.

Balthasar V. 1963b. *Monographic der Scarabaeidae und Aphodiidae der Palaearktischen und Orientalischen Region (Coleoptera: Lamellicornia).* Volume 2. Verlag der Tschechoslowakischen Akademie der Wissenschaften. Prag, 627 pp.

Baraud J. 1985. *Coleopteres Scarabaeoidea, Faune du nord de l' Afrique du Maroc au Sinai*. Lechevalier, Paris.

Baraud J. 1992. *Coleopteres Scarabaeoidea: Fauna De France 78*. Publication de la Fèdèration Franáaise des Socièt'ès de Sciences Naturelles, et de la Societe Linnvenne, 856 pp.

Bartholomew G.A. & Heinrich B. 1978. Endothermy in African dung beetles during flight, ball making, and ball rolling. *Journal of Experimental Biology*, 73: 65–83.

Bates H.W. 1891. Coleoptera. In: Whymper E., editor. *Supplementary appendix to travels amongst the great Andes of the Equator*, 7–39. Murray, London.

Begon M., Harper J.L. & Townsend C.R. 1996. *Ecology, Individuals, Populations and Communities*, 3rd edition. Oxford: Blackwell Science.

Bergstrom B.C., Maki R.L. & Werner B.A. 1976. Small dung beetles as biological control agents: laboratory studies of beetle action on trichostongylid eggs in sheep and cattle feces. *Proc. Helm. Soc. Wash.,* 43: 171–174.

Bertone M., Green J., Washburn S., Poore M., Sorenson C. & Watson D.W. 2005. Seasonal activity and species composition of dung beetles

(Coleoptera: Scarabaeidae and Geotrupidae) inhabiting cattle pastures in North Carolina. *Annals of Entomological Society of America*, 98(3): 309–321.

Berytenbach W. & Berytenbach G.J. 1986. Seasonal patterns in the dung feeding Scarabaeidae in the southern Cape. *Journal of the Entomological Society of Southern Africa*, 49: 359–366.

Biswas S. & Chatterjee S.K. 1985. Insecta: Coleoptera: Scarabaeidae: Coprinae. Fauna of Namdapha Wildlife Sanctuary. *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,* 84(1–4): 79–96.

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

Biswas S. 1978a. Studies on scarab beetles (Coleoptera: Scarabaeidae) of north-east 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 scarab beetles (Coleoptera: Scarabaeidae) of north-east India Part II: Three new species and two new records from India. *Journal of Bombay Natural History Society,* 76: 339–344.

Biswas S., Mukhopadhyaya P., Saha S.K., Basu C.R., Chatterjee S.K., Chakraborty S.K., Biswas D.N., Halder S.K., Ghosh S.K. & Chakraborty P. 1997. Coleoptera. State fauna series, fauna of Delhi. *Zoological Survey of India*, 6: 325–353.

Blackwelder R.E. 1944. Checklist of the coleopterous insects of Mexico, Central America, the West Indies and South America. *Bull. USNM,* 185 (2): 189–341.

Bossuyt F., Meegaskumbura M., Beenaerts N., Gower J.D., Pethiyagoda R., Roelants K., Mannaert A., Wilkinson M., Bahir M.M., Arachchi M.K., Peter K.L.N., Schneider J.C., Oommen V.O. & Milinkovitch C.M. 2004. Local endemism within the Western Ghats, Sri Lanka biodiversity hotspot. *Science*, 306: 479–481.

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: 573–583.

Boucomont A. 1914. Les Coprophages de l'Archipel Malais. *Annales de la Societe Entomologique de France*, 83: 238–350.

Brown K.S.J. 1997. Diversity, disturbance, and sustainable use of Neotropical forests: insects as indicators for conservation monitoring. *Journal of Insect Conservation*, 25–42.

Browne D.J. & Scholtz C.H. 1995. Phylogeny of the families of Scarabaeoidea (Coleoptera) based on characters of the hind wing articulation, hind wing base and wing venation. *Systematics Entomol*ogy, 20: 145–173.

Browne D.J. & Scholtz C.H. 1998. Evolution of the scarab hind wing articulation and wing base of the Scarabaeoidea (Coleoptera) with notes on phylogenetic trends. *Bon. Zool. Mon.*, 40: 1–200.

Bullock S.H., Mooney H.A. & Medina E. 1995. *Seasonally dry tropical forests*. Cambridge University Press, Cambridge, United Kingdom.

Burgos A. & Maass M.J. 2004. Vegetation change associated with land-use in tropical dry forest areas of Western Mexico. *Agriculture*, *Ecosystems and Environment*, 104: 475–481.

Cambefort Y. 1984. Etude ecologique des Coleopteres Scarabaeidae de Cote d' Ivoire. *Trav. Cherch. Lamto*., 3: 1–294.

Cambefort Y. 1985. Les especes orientales du genre *Cleptocaccobius* (Coleoptera, Scarabaeidae). *Revue Francaise d'Entomologie*, 7(3): 125–130.

Cambefort Y. 1991. Dung beetles in tropical savannas. In: Hanski I. & Cambefort Y., editors. *Dung beetle ecology*, 156–178. Princeton University Press.

Cambefort Y. & Hanski I. 1991. Dung beetle population biology. In: Hanski I. & Cambefort Y., editors. *Dung beetle ecology*, 36–50. Princeton University Press.

Cambefort Y. & Walter P. 1991. Dung beetles in tropical forests in Africa. In: Hanski I. & Cambefort Y., editors. *Dung beetle ecology*, 198–210. Princeton University Press.

Carne P.B. 1956. An ecological study of the pasture scarab *Aphodius howitti* Hope. *Australian Journal of Zoology*, 4: 259–318.

Caveney S., Scholtz C.H. & McIntyre P. 1995. Patterns of daily flight activity in onitine dung beetles (Scarabaeinae: Onitini). *Oecologia*, 103: 444–452.

Chandra K. & Gupta D. 2012. Diversity and composition of dung beetles (Scarabaeidae: Scarabaeinae and Aphodiinae) assemblages in Singhori Wildlife Sanctuary, Raisen, Madhya Pradesh (India), *Mun. Ent. Zool.*, 7(2).

Chandra K. & Ahirwar S.C. 2005. Scarabaeid beetles (Coleoptera) of Kanha Tiger Reserve, Madhya Pradesh. *Zoological Survey of India*, 147–155.

Chandra K. & Ahirwar S.C. 2007. Insecta: Coleoptera: Scarabaeidae. In: Chandra K., editor. Fauna of Madhya Pradesh (including Chhattisgarh), State Fauna series, 15: 273–300. *Zoological survey of India*, 1–564.

Chandra K. & Rajan P.T. 2004. Faunal diversity of Mount Harriett national park (south Andaman): Conservation Area series. *Zoological Survey of India*, 17: 142.

Chandra K. & Singh R.K. 2004. On a collection of Scarabaeid beetles (Coleoptera) from Pachmarchi biosphere reserve, Madhya Pradesh. *Records of the Zoological Survey of India,* 102(3–4): 43–46.

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

Chandra K. 2005. Insecta: Coleoptera: Scarabaeidae. Fauna of western Himalaya. *Zoological Survey of India*, 2: 141–155.

Chatterjee S.K. & Biswas S. 2000. Insecta: Coleoptera: Scarabaeidae. State fauna series 7: Fauna of Tripura. *Zoological Survey of India*, 3: 87–98.

Cheng W. 1999. Rhizosphere feedbacks in elevated CO_2. *Tree Physiology*, 19: 313–320.

Clarke K.R. & Gorley R.N. 2001. Primer v5. User manual/ tutorial, PRIMER-E, Plymouth UK.

Clifford H.T. & Stephenson W. 1975. *An Introduction to Numerical Classification*. Academic Press, 229 pp.

Creutzer C. 1799. *Entomologische Versuche*. Schaumourg, Wien.

Davis A.J. 1999. Species packing in tropical forests: diel flight activity of rainforest dung-feeding beetles (Coleoptera: Aphodidae, Scarabaeidae, Hybosoridae) in Borneo. *Raffles Bulletin of Zoology*, 47: 473–486.

Davis A.J. 2000a. Species richness of dung-feeding beetles (Coleoptera: Aphodiidae, Scarabaeidae, Hybosoridae) in tropical rainforest at Danum Valley, Sabah, Malaysia. *Coleopterist's Bulletin*, 54: 221–231.

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

Davis A.J. & Sutton S.L. 1998. The effects of rainforest canopy loss on arboreal dung beetles in Borneo: implications for the measurement of biodiversity in derived tropical ecosystems. *Diversity and Distributions*, 4: 167–173.

Davis A.J., Holloway J.D., Huijbregts H., 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: 593–616.

Davis A.J., Huijbregts J. & 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: 281–292.

Davis A.J., Huijbregts J., Kirk-Spriggs A.H., Krikken J. & Sutton S.L. 1997. The ecology and behaviour of arboreal dung beetles in Borneo. In: Stork N.E., Adis J. and Didham R., editors. *Canopy Arthropods*, 417–432. Chapman and Hall, London, UK.

Davis A.L.V. 1987. Geographical distribution of dung beetles (Coleoptera: Scarabaeidae) and their seasonal activity in south western Cape Province. *Journal of Entomological Society of South Afr*ica, 50 (2): 275–285.

Davis A.L.V. 1993a. Biogeographical groups in a southern African, winter rainfall, dung beetle assemblage (Coleoptera: Scarabaeidae) consequences of climatic history and habitat fragmentation. *African Journal of Ecology*, 31: 306–327.

Davis A.L.V. 1993b. Alpha diversity patterns of dung beetle assemblages (Coleoptera: Scarabaeidae, Hydrophilidae, Histeridae, Staphylinidae) in the winter rainfall region of South Africa. *African Entomology*, 1: 67–80.

Davis A.L.V. 1993c. Annual age structure patterns in Afrotropical dung beetles (Coleoptera: Scarabaeidae) under winter rainfall climate. *Journal of African Zoology*, 107: 397–411.

Davis A.L.V. 1994a. Associations of Afrotropical Coleoptera (Scarabaeidae, Aphodiidae, Staphylinidae, Hydrophilidae, Histeridae) with dung and decaying matter: implications for selection of fly-control agents for Australia. *Journal of Natural History,* 28: 383–399.

Davis A.L.V. 1994b. Compositional differences between dung beetle assemblages (Coleoptera: Scarabaeidae) in winter and summer rainfall climates. *African Entomology*, 2: 45–51.

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

Davis A.L.V. 1994d. Community organization in a South African, winter rainfall, dung beetle assemblage (Coleoptera: Scarabaeidae). *Acta Oecologica*, 15: 727–738.

Davis A.L.V. 1995. Daily weather variation and temporal dynamics in an Afrotropical dung beetle community (Coleoptera: Scarabaeidae). *Acta Oecologica*, 16: 641–656.

Davis A.L.V. 1996a. Diel and seasonal community dynamics in an assemblage of coprophagous, Afrotropical, dung beetles (Coleoptera: Scarabaeidae

s. str., Aphodiidae, Staphylinidae: Oxytelinae). *Journal of African Zoology,* 110: 291– 308.

Davis A.L.V. 1996b. Habitat associations in a South African, summer rainfall, dung beetle community (Coleoptera: Scarabaeidae, Aphodiidae, Staphylinidae, Histeridae, Hydrophilidae). *Pedobiologia*, 40: 260–280.

Davis A.L.V. 1996c. Seasonal dung beetle activity and dung dispersal in selected South African habitats: implications for pasture improvement in Australia. *Agriculture, Ecosystem and Environment*, 58: 157–169.

Davis A.L.V. 1996d. Community organization in dung beetles (Coleoptera: Scarabaeidae): differences in body size and functional group structure between habitats. *African Journal of Ecology*, 34: 258–275.

Davis A.L.V. 1997. Climatic and biogeographical associations of southern African dung beetles (Coleoptera: Scarabaeidae s. str.). *African Journal of Ecology*, 35: 10–38.

Davis A.L.V. 2002. Dung beetle diversity in South Africa: influential factors, conservation status, data inadequacies and survey design. *African Entomology,* 10(1): 53–65.

Davis A.L.V. & Dewhurst C.F. 1993. Climatic and biogeographical associations of Kenyan and north Tanzanian dung beetles (Coleoptera: Scarabaeidae). *African Journal of Ecology*, 31: 290–306.

Davis A.L.V., Scholtz C.H. & Philips T.K. 2002. Historical biogeography of Scarabaeine dung beetles. *Journal of Biogeography*, 29: 1217–1256.

Deloya C., Parra-Tabla V. & Delfin-Gonzalez H. 2007. Fauna of Scarabaeidae-Laparosticti and Trogidae (Coleoptera: Scarabaeoidea) associated with Cloud Forest, shaded coffee plantations and transformed communities in Central Veracruz, Mexico. *Neotropical Entomology*, 36(1): 5–21.

Diaz A., Galante E. & Favila M.E. 2010. The effect of the landscape matrix on the distribution of dung and carrion beetles in a fragmented tropical rain forest. *Journal of Insect Science*, 10: 1–81.

Doube B.M. 1991. Dung beetles of South Africa. In: Hanski I. & Cambefort Y., editors. *Dung Beetle Ecology*, 133–155. Princeton University Press.

Doube B.M., Macqueen A., Ridsdill-Smith T.J. & Weir T.A. 1991. Native and introduced dung beetles in Australia. In: Hanski I. & Cambefort Y., editors. *Dung Beetle Ecology,* 255–278. Princeton University Press.

Durães R., Martins W.P. & Vaz-De-Mello F.Z. 2005. Dung Beetle (Coleoptera: Scarabaeidae) Assemblages across a Natural Forest-Cerrado Ecotone in Minas Gerais, Brazil. *Neotropical Entomology*, 34(5): 721–731.

Edwards P.B. 1988. Field ecology of a brood-caring dung beetle *Kheper nigroaeneus*, habitat predictability and life history strategy. *Oecologia*, 75: 527–534.

Edwards P.B. 1991. Seasonal activity in the dung of African grazing mammals, and its consequences for coprophagous insects. *Funct. Ecol.*, 5: 617–628.

Errouissi F., Jay-Robert P., Lumaret J.P. & Plau P. 2004. Composition and structure of dung beetle (Coleoptera: Aphodiidae, Geotrupidae, Scarabaeidae) assemblages in mountain grasslands of the Southern Alps. *Ann. Entomol. Soc. Am.,* 97: 701–709.

Escobar F. 1997. Estudio de la comunidad de coleópteros coprófagos (Scarabaeidae) en un remanente de bosque seco al norte del Tolima, Colombia. *Caldasia*, 19: 419–430.

Escobar F. 2000. Diversidad de colepteros coprofagos (Scarabaeidae: Scarabaeinae) en un mosaico de habitats en la reserva natural Nukak, Guiviare, Colombia. *Acta Zoolologica Mexicana*, 79: 103–121.

Escobar F. 2004. Diversity and composition of dung beetle (Scarabaeinae) assemblages in a heterogeneous Andean landscape. *Trop. Zool.*, 17: 123–136.

Escobar F. & Chacon de Ulloa P. 2000. Distribución especialy temporal en un gradient de sucesión de la fauna de coleopteros coprófagos (Scarabaeinae, Aphodinae) en un bosque tropical montano, Narino-Colombia. *Revista Biología Tropical*, 48(4): 961–975.

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, Veracruz, Mexico. *Journal of Tropical Ecology*, 7: 459–474.

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: 1903–1918.

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

Estrada A., Coates-Estrada R., Anzures A. & Cammarano P. 1998. Dung and carrion beetles in tropical rainy forest fragments and agricultural habitats at Los Tuxtlas, Mexico. *J. Trop. Ecol.*, 14: 577–593.

Fabricius J.C. 1775. *Systema Entomologicae*, *sistens Insectorum Classes*, *Ordines, Genera, Species*, *adjectis Synonymis*, *Locis*, *Descriptionibus*, *Observationibus*. Kortii, Flensburg and Leipzig, xxxii + 832 pp.

Fabricius J.C. 1781. *Species Insectorum*, Bohn Hamburg and Kilonii 1(viii): 552 pp.

Fabricius J.C. 1798. *Supplementurn Entomologiae Systematicae*. Hafniae.

Fabricius J.C. 1801. *Systema Eleutheratorum secundum Ordines*, *Genera*, *Species*: *adjectis Synonymis*, *Locis*, *Observationibus*, *Descriptionibus. Tomus I*. Bibliopolii Academici Novi, Kiel, xxiv + 506 pp.

Favila M.E. & Hallfter G. 1997. The use of indicator groups for measuring biodiversity as related to community structure and function. *Acta Zoologica Mexicana*, 72: 1–25.

Feer F. & Pincebourde S. 2005. Diel flight activity and ecological segregation with in an assemblage of tropical forest dung and carrion beetles. *Journal of Tropical Ecology*, 21: 21–30.

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: 129–142.

Feer F. 2000. Les Coléoptères coprophages et nécrophages (Scarabaeidae s. str. et Aphodiidae) de la forêt de Guyane Française: Composition spécifique et structure des peuplements. *Annales de la Société Entomologique de France (Nouvelle série)*, 36: 29–43.

Ferreira M.C. 1972. Os escarabıdeos de Africa (sul do Saara). *Revista de Entomologia de Mocambique*, 11: 5–1088.

Fincher G.T., Blume R.R., Hunter J.S. & Beerwinkle K.R. 1986. Seasonal distribution and diel flight activity of dung-feeding scarabs in open and wooded pasture in east-central Texas. *Southwestern Entomological Supplement*, 10: 1–35.

Fincher G.T., Davis R. & Stewart T.B. 1971. Flight activity of coprophagous beetles on a swine pasture. *Annals of Entomological Society of America*, 64: 855–860.

Floate K.D. & Gill B.D. 1998. Seasonal activity of dung beetles (Coleoptera: Scarabaeidae) associated with cattle dung in southern Alberta and their geographic distribution in Canada. *Can. Entomol.*, 130: 131–151.

Fourcroy A.F.de 1785. Entomologia parisiensis, sive catalogus insectorum quae in agro parisiensi reperiuntur. Pars secunda, Via et Aedibus Serpentineis, (1): 233–544.

Galante E., García-Román M., Barrera I. & Galindo P. 1991. Comparison of spatial Gases. *Glob. Chang. Biol.,* 4: 745–758.

Gardner T.A., Hernández M.I.M., Barlow J. & Peres C.A. 2008. Understanding the biodiversity consequences of habitat change: the value of secondary and plantation forests for neotropical dung beetles. *J. Appl. Ecol.,* 1–11.

Gill B.D. 1991. Dung beetles in Tropical American Forests. In: Hanski I. & Cambefort Y., editors. *Dung Beetle Ecology,* 211–229. Princeton University Press.

Gillet J.J.E. 1908. Coprides d' Afrique tropicalc. *Mem. Soc. Ent. Belg.,* XVI: 63–81.

Gillet J.J.E. 1911. Coprophaga Africana. *Ann. Soc. Ent. Belg.,* 55: 308–312.

Gillet J.J.E. 1924. Scarabaeides coprophages de Sumatra. *Ann. Soc. Ent. Belg*., LXIV: 102–104.

Gillet J.J.E. 1925. Deux Heliocopris nouveaux d'Afrique occidentale. *Bulletin et Annales de la Société entomologique de Belgique*, 66: 359–361.

Gillet J.J.E. 1935. Schwedisch-chinesische wissensch. Expedition nach den nordwestl. Provinzen Chinas- Scarabaeidae. *Ark. F. Zool*., 27 (3): 1–12.

González-Maya J.F. & Mata-Lorenzen J. 2008. Dung-beetles (Coleoptera: Scarabaeidae) from the Zona Protectora Las Tablas, Talamanca, Costa Rica. *Check List* 4(4): 458–463.

Gory M. 1833. *Monographie du genre Sisyohe*. Chez Méquignon-Marvis Père et Fils, Libraires, Paris, pp. 1–16.

Halffter G., Pineda E., Arellano L. & Escobar F. 2007. The instability of copronecrophagous beetles assemblages (Coleoptera: Scarabaeinae) in a mountainous tropical Landscape of Mexico. *Environmental Entomology*, 36: 1397–1407.

Halffter G. & Arellano L. 2002. Response of dung beetle diversity to human-induced changes in a tropical landscape. *Biotropica*, 34: 144–154.

Halffter G. & Edmonds W.D. 1982. The Nesting Behavior of Dung Beetles (Scarabaeinae): An Ecological and Evolutive Approach. *Instituto de Ecologia*, AC, Mexico, DF.

Halffter G. & Favila M.E. 1993. The Scarabaeinae (Insecta: Coleoptera) an animal group for analysing, inventorying and monitoring biodiversity in tropical rainforest and modified ecosystems. *Biology International*, 27: 15–21.

Halffter G. & Mathews E.G. 1966. The natural history of dung beetles of the sub family Scarabaeinae (Coleoptera, Scarabaeidae). *Folia Entomologica Mexicana*, 12–14: 1–132.

Halffter G. 1991. Historical and ecological factors determining the geographical distribution of beetles (Coleoptera: Scarabaeidae: Scarabaeinae). *Folia Entomologica Mexicana*, 82: 195–238.

Halffter G., Favila M.E. & Halffter V. 1992. A comparative study of the structure of the scarab guild in Mexican tropical rain forest and derived ecosystems. *Folia Entomologica Mexicana*, 84: 131–156.

Hanski I. 1986. Individual behaviour, population dynamics and community structure of *Aphodius* (Scarabaeidae) in Europe, *Acta Oecologica Oecologia Generalis*, 7: 171–187.

Hanski I. 1989. Dung beetles. In: Lieth H. & Werger M.J.A., editors. *Tropical Rain Forest Ecosystems. Biogeographical and Ecological Studies*, 489–511. Ecosystems of the World 14B.

Hanski I. 1990. Density dependence, regulation and variability in animal populations. *Philosophical Transactions of the Royal Society of London*, B 330: 141–150.

Hanski I. & Cambefort Y. 1991a. *Dung beetle ecology*, Princeton University Press, Princeton, xiii: 481 pp.

Hanski I. & Cambefort Y. 1991b. Resource partitioning. In: Hanski I. and Cambefort Y., editors. *Dung Beetle Ecology*, 330–349. Princeton University Press.

Hanski I. & Cambefort Y. 1991c. Competition in dung beetles. In: Hanski I. & Cambefort Y., editors. *Dung Beetle Ecology*, 305–329. Princeton University Press.

Hanski I. & Krikken J. 1991. Dung beetles in Tropical Forests in South-East Asia. In: Hanski I. & Cambefort Y., editors. *Dung Beetle Ecology*, 179–197. Princeton University Press.

Hanski I. 1983. Distributional ecology and abundance of dung and carrion-feeding beetles (Scarabaeidae) in tropical rain forests in Sarawak, Borneo. *Acta Zool. Fenn.,* 167: 1–45.

Hanski I. 1991. The dung insect community. In: Hanski I. & Cambefort Y., editors. *Dung Beetle Ecology*, 5–21. Princeton University Press.

Harold E. von. 1867. Diagnosen neuer Coprophagen. *Coleopterologische Hefte,* 2, 94–100.

Harold E. von. 1868. Monographie der Gattung *Canthon. Berliner Entomologische Zeitung*, 12: 1–141.

Harvey C., Gonzalez J. & Somarriba E. 2006. Dung Beetle and Terrestrial Mammal Diversity in Forests, Indigenous Agroforestry Systems and Plantain Monocultures in Talamanca, Costa Rica. *Biodiversity conserv.,* 15: 555–585.

Hernández M.I.M. 2005. Artrópodes: besouros Scarabaeidae (Coleoptera) do Curimataú, Paraíba. In: Araújo F.S., Rodal M.J.N. & Barbosa M.R.V., editors. *Análise das variações da biod iversidade do bioma Caatinga para suporte a estratégias regionais de conservação*, 369–380. Ministério do Meio Ambiente, Brasília (in Portuguese).

Hernández M.I.M. 2007. Besouros escarabeíneos (Coleoptera: Scarabaeidae) da Caatinga paraibana, Brasil. *Oecologia Brasiliensis* 11: 356–364.

Hill C.J. 1993. The species composition and seasonality of an assemblage of tropical Australian dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae). *Australian Entomologist*, 20: 121–126.

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

Hingston R.W.G. 1923. *A Naturalist in Hindustan*. H.F. and G. Witharby, London, 292 pp.

Holter P. 2000. Particle feeding in *Aphodius* dung beetles (Scarabaeidae): old hypotheses and new experimental evidence. *Functional Ecology*, 14: 631–637.

Hope F.W. 1837. The coleopterist's manual, containing the lamellicorn insects of Linneus and Fabricius. London.

Horgan F.G. 2001. Burial of bovine dung by coprophagous beetles (Coleoptera: Scarabaeidae) from horse and cow grazing sites in El Salvador. *Eur. J. Soil Biol.*, 37: 103–111.

Horgan F.G. 2002. Shadyfield boundaries and the colonization of dung by coprophagous beetles in Central American pastures. *Agriculture, Ecosystem and Environment,* 92: 25–39.

Horgan F.G. 2007. Dung beetles in pasture landscapes of Central America: proliferation of synanthropogenic species and decline of forest specialists. *Biodiversity and Conservation*, 16: 2149–2165.

Houston W.W.K. & McIntyre P. 1985. The daily onset of flight in the crepuscular dung beetle *Onitis alexis*. *Entomologia Experimentalis et Applicata*, 39: 223–232.

Howden H.F. & Gill B.D. 1987. New species and new records of Panamian and Costa Rican Scarabaeinae (Coleoptera: Scarabaeidae). *Coleopterists Bulletin*, 41(3): 201–224.

Howden H.F. & Nealis V.G. 1975. Effects of clearing in a tropical rain forest on the composition of the coprophagous scarab beetle fauna (Coleoptera). *Biotropica*, 7: 77–83.

Howden H.F. & Young O.P. 1981. Panamerican Scarabaeinae: taxonomy, distribution, and habits (Coleoptera, Scarabaeidae). *Contributions American Entomological Institute*, 18: 1–204.

Howden H.F., Howden A.T. & Storey R.I. 1991. Nocturnal perching of Scarabaeidae dung beetles (Coleoptera, Scarabaeidae) in an Australian tropical rain forest. *Biotropica,* 23: 51–57.

Huston M.A. 1994. *Biological diversity- the coexistence of species on changing landscape*. Cambridge University Press, Cambridge, xix: 681 pp.

Hutton S.A. & Giller P.S. 2003. The effects of the intensification of agriculture on northern temperate dung beetle communities. *Journal of Appied Ecology*, 40: 994–1007.

Illiger J.C.W. 1798. In J. Kugelann, Verzeichniss der Kafer Preussens, ausgearbeitet von Illiger. Halle.

Illiger J.C.W. 1803. Verzeichniss der in Portugall einheimischen Kafer. Erste Lieferung. *Mag. Insektenk.*, 2: 186–258.

Jameson M.L. 1989**.** Diversity of coprophagous Scarabaeidae (Coleoptera) in grazed versus ungrazed sandhills prairie in Western Nebraska. *Trans. Nebr. Acad. Sci.*, 17: 29–35.

Jankielsohn A., Scholtz C.H. & Louw S.V. 2001. Effect of Habitat Transformation on Dung Beetle Assemblages: A Comparison Between a

South African Nature Reserve and Neighboring Farms. *Environ. Entomol*., 30 (3): 474–483.

Janssens A. 1940. Monographie des gymnopleurides. Memoires de Musee Royal d'Histoire Nuturelle de Belgique, 2(16): 3–74.

Janssens A. 1949. Contribution a l' etude des Coleopteres Lamellicornes. Table synoptique et essai de classification practique des Coleopteres Scarabaeidae. *Bull. Roy. Sci. Nat. Belg*., 25: 1–30.

Janzen D.H. 1983. Seasonal change in abundance of large nocturnal dung beetles (Scarabaeidae) in a Costa Rican deciduous forest and adjacent horse pasture. *Oikos*, 41: 274–283.

Janzen D.H. 1988. Tropical dry forests: the most endangered major tropical ecosystem. In: Wilson E.O., editor. *Biodiversity*, 130–137. National Academy Press, Washington.

Joseph K.J. 1991. SEM study of the stridulatory organs in the giant elephant dung beetle, *Heliocopris dominus* Bates (Scarabaeidae) with observations on the significance of the sound production. *Entomon,* 16: 319–322.

Joseph K.J. 1994. Sexual dimorphism and intra-sex variations in the elephant dung beetle, *Heliocopris dominus* (Coprinae: Scarabaeidae). *Entomon,* 19: 165–168.

Joseph K.J. 1998. Biology and breeding behaviour of the elephant dung beetle, *Heliocopris dominus* Bates (Coprinae: Scarabaeidae). *Entomon,* 23: 325–329.

Joseph K.J. 2003. The life cycle, ecological role and biology of immature stages of *Heliocopris dominus* Bates (Coleoptera: Scarabaeidae: Coprinae). *Entomon,* 28(3): 247–251.

Kerala Forests and Wildlife Department Management Plan 2002–2011. Chinnar wildlife sanctuary, Western Ghats, Kerala, India. http//www.chinnar.org/html/managementplan.htm.

Kerala Forests and Wildlife Department, Government of Kerala. 2004. Accessed on March 03, 2010. http://www.keralaforest.gov.in/html/flora/index.htm.

Kingston T.J. 1977. Natural manuring by elephants in the Tsavo Natural Park, Kenya. *Ph.D. Thesis*. Univ. of Oxford, Oxford.

Kirby W. 1828. A description of some Coleopterous insects in the collection of the Rev. F.W. Hope, F.L.S. *Zool. J.,* 3:520–525.

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

Kohlmann & Śanchez-CoÍon 1984. Structure of a Scarabaeinae community: A numerical- behavioural study (Coleoptera: Scarabaeinae). *Acta Zoologica Mex*ico, 2: 1–27.

Kohlmann B. 1991. Dung beetles in subtropical north America. In: Hanski I. & Cambefort Y., editors. *Dung beetle ecology*, 116–132. Princeton University Press, Princeton.

Krajcik M. 2006. Checklist of Scarabaeoidea of the world. 1. *Scarabaeinae Animma. X, Supplement,* 3:1–189.

Krausse A.H. 1907a. Coprophagen- Leben auf Sardinien im Herbste, *Zeitschrift fur Wissenschaft und Insecten- biologie* 3: 30–32.

Krausse A.H. 1907b. Mistkafer leben im Fruhjahr auf Sardinien *Zeitschrift fur Wissenschaft und Insecten- biologie* 3: 286–288.

Krell-Westerwalbesloh S., Krell F.T. & Kelinsenmair E. 2004. Diel separation of Afrotropical dung beetle guilds- avoiding competition and neglecting resources (Coleoptera: Scarabaeoidea). *Journal of Natural History*, 38: 2225–2249.

Krell F.T., Krell-Westerwalbesloh S., Weiß I., Eggleton P. & Linsenmair K.E. 2003. Spatial separation of Afrotropical dung beetle guilds: a trade-off between competitive superiority and energetic constraints (Coleoptera: Scarabaeidae). *Ecography*, 26: 210–222.

Krell-Westerwalbesloh S., Krell F.T. & Kelinsenmair E. 2004. Diel separation of Afrotropical dung beetle guilds-avoiding competition and neglecting resources (Coleoptera: Scarabaeoidea). *Journal of Natural History,* 38: 2225–2249.

Krikken J. 2009. Drepanocerine dung beetles: a group overview, with description of new taxa (Coleoptera: Scarabaeidae: Scarabaeinae). *Haroldius*, 4, 3–30.

Lacordaire M.T. 1856. Histoire Naturelle des Insectes-Genera des Coleopteres. Librairie Encyclopedique de Roret, Paris.

Larsen T.H. & Forsyth A. 2005. Trap spacing and transect design for dung beetle biodiversity studies. *Biotropica,* 37(2): 322–325.

Latha M. 2011. Systematics and ecology of dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae) in the Nelliampathi region of south Western Ghats. Ph.D. thesis submitted to University of Calicut, 1–240.

Latha M., Cuccodoro G., Sabu T.K. & Vinod K.V. 2011. Taxonomy of the dung beetle genus *Ochicanthon* Vaz-de-Mello (Coleoptera: Scarabaeidae: Scarabaeinae) of the Indian subcontinent, with notes on distribution patterns and flightlessness. *Zootaxa,* 2745, 1–29.

Latreille P.A. 1796. Precis de caracteres generiques des insectes, disposes dans un order naturel. Bordeaux.

Latreille P.A. 1802. Histoire naturelle generale et particuliere des crustacees et des insectes, Vol. 3. Paris.

Latreille P.A. 1807. Genera Crustaceorum et Insectorum secundum ordinem naturalem in familias disposita, iconibus exemplisque. Parisiis et Argentorate.

Lawrence J.F. & Newton A.F. Jr. 1995. Families and subfamilies of Coleoptera (with selective genera, notes, reference and data on family-group names). In: Pakaluk A.F.J. & Lipiski S.A., editors. *Biology*, *Phylogeny and Classification of Coleoptera*, 779–1006. Muzeum i Instytut Zoologii PAN, Warszawa, Poland.

Liberal C.N. 2008. Diversidade de Scarabaeinae (Coleoptera: Scarabaeidae) em uma area de Caatinga na regiao de Parnamirim, PE. In: Leal I.R., Almeida-Cortez J. & Santos J.C., editors. *Ecologia da Caatinga*, 79–87. Editora Universitaria.

Liberal C.N., Isidro de Farias Â.M., Meiado M.V., Filgueiras B.K.C. & Iannuzzi L. 2011. How habitat change and rainfall affect dung beetle diversity in Caatinga, a Brazilian semi-arid ecosystem. *Journal of Insect Science* 11: 1–114.

Linnaeus K. 1758. Systema Nature per regna tria naturae (etc.). Editio X.

Löbl I. & Smetana A. 2006. *Catalogue of Palaearctic Coleoptera,* volume 3. Apollo, Stenstrup, Denmark, 690 pp.

Lobo J.M. 2000. Species diversity and composition of dung beetle (Coleoptera: Scarabaeoidea) assemblages in North America. *Can. Entomol.,* 132: 307–321.

Lobo J.M. 2001. Decline of roller dung beetle (Scarabaeinae) populations in the Iberian Peninsula during the 20th century. *Biological Conservation*, 97: 43–50.

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 Distrib.* 12: 111–123.

Lobo J.M., Martin Piera F. & Veiga C.M. 1988. Las trampas pitfall con cebo, sus posibilidades en el estudio de Scarabaeoidea (Col.). I. Caracteristicas determinantes de su capacidad de captura. *Rev. Ecol. Biol. Sol.,* 25: 77–100.

Loozada J.N.C. & Lopez F.S. 1997. The dung beetle community from an Atlantic forest fragmentation. *The Revista Brasileira de Entomologia*, 41: 117–121.

Lopera A. 1996. Distribución y diversidad de escarabajos coprófagos (Scarabaeidae: Coleoptera) en tres relictos de bosque altoandino (Cordillera Oriental, Vertiente Occidental, Colombia). Trabajo de Grado. Pontificia Universidad Javeriana. Santafé de Bogotá.

Lopes P.P. & Louzada J.N.C. 2005. Besouros (Scarabaeidae e Histeridae). In: Juncá F.A., Funch L. & Rocha W., editors. *Biodiversidade e Conservação da Chapada Diamantina*, 284–298. Brasília: Ministério do Meio Ambiente.

Lopes P.P., Louzada J.N.C. & Vaz-de-Mello F.Z. 2006. Organization of dung beetle communities (Coleoptera, Scarabaeidae) in areas of vegetation re-establishment in Feira de Santana, Bahia, Brazil. Sitientibus Sér. Ciên. *Biol.*, 6: 261–266.

Lumaret J.P. 1983. Structure des peuplements de coprophages Scarabaeidae en region mediterraneenne franc aise: Relations entre lesconditions ecologiques et quelques parametres biologiques des especes. *Bulletin de la Societe Entomologique de France*, 88: 481–495.

Lumaret J.P & Stiernet N.1991. Montane dung beetles. In: Hanski I. & Cambefort Y., editors. *Dung beetle ecology*, 242–254. Princeton University Press, Princeton.

Lumaret J.P. & Iborra O. 1996. Separation of trophic niches by dung beetles (Coleoptera, Scarabaeoidea) in overlapping habitats. *Pedobiologia*, 40: 392–404.

Lumaret J.P. & Kim J.I. 1989. Les larves du genre *Onthophagus* Latreille, 1802. 4 : Les sous genres *Onthophagus*, *Gibbonthophagus*, *Furconthophagus*, *Phanaeomorphus*, et *Parentius* (Coleoptera, Scarabaeidae). *Ann. Soc. Entomol. Fr. (NS),* 25: 235–241.

Lumaret J.P. & Kirk A.A. 1991. South temperate dung beetles. In: Hanski I. & Cambefort Y., editors. *Dung beetle ecology*, 97–115. Princeton University Press.

Lumaret J.P., Kadiri N. & Bertrand M. 1992. Changes in resources: consequences for the dynamics of dung beetle communities. *Journal of Applied Ecology*, 29: 349–356.

Madle H. 1934. Zur Kenntnis der Morphologie, Okologie und Physiologie von *Aphodius rufi pes* L. und einigen verwandten Arten. *Zoologische Jahrbucher. Abteilung fur Anatomie und Ontogenie der Tiere*, 58: 303–397.

Magurran A.E. 2004. *Measuring Biological Diversity*. Blackwell Publishing Ltd., pp. 256

Martin-Piera F. & Zunino M. 1983. *Amphionthophagus*, nuovo sotogener e di *Onthophagus* Latr. (Coleoptera, Scarabaeidae). *Bulletin of the Museo Regionale di Scienze Naturali Bollettino* (*Torino*), 1: 59–76.

Martin-Piera F. & Zunino M. 1986. Analisi systematica, filogenetica e biogeografica di un gruppo di specie del sottogener e Palaeonthophagus Zunino, 1979 (Coleoptera, Scarabaeidae, genere Onthophagus): II gruppo ovatus. *Bulletin of the Museo Regionale di Scienze Naturali Bollettino* (*Torino*), 4: 413–467.

Martin-Piera F. 1986. The palearctic species of the subgenus *Parentius* Zunino, 1979 (Coleoptera, Scarabaeidae, Onthophagini). *Bull. Mus. Reg. Sci. Nat. Torino.,* 4: 77–122.

Martin-Piera F. 2000. Familia Scarabaeidae. In: Ramos Sanchez M.A., *et al.* (eds.) *Coleoptera, Scarabaeoidea. Fauna Iberica*, 215–446. Museo Nacional de Ciencias Naturales, CSIC, Madrid.

Mathew G. 2004. Biodiversity Documentation for Kerala.Part.7: Insects. KFRI Handbook No: 17. Kerala Forest Research Institute.

McGeoch M.A. & Chown S.L. 1998. Scaling up the value of bioindicators. *Trends in Ecology and Evolution*, 13: 46–47.

McGeoch M.A. 1998. The selection, testing & application of terrestrial insects as bioindicators. *Biological Reviews*, 73: 181–201.

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: 661–672.

Medina A.M. & Lopes P.P. 2014. Seasonality in the dung beetle community in a Brazilian tropical dry forest: Do small changes make a difference? *Journal of Insect Science*, 14: 1–123.

Miranda C.H.B., Santos J.C.C.D. & Bianchin I. 1998. Contribution of *Onthophagus gazella* to soil fertility improvement by bovine fecal mass incorporation into the soil. 1. Greenhouse studies. *Rev. Brasil. Zootec*., 27: 681–685.

Mittal I.C. 2011. Synoptic key to Indian species of genus Garreta Janssen (Coleopera: Scarabaeidae: Scarabaeinae) with a new species from Haryana (India). *Journal of entomological Research*, 35(3): 295–298.

Mittal I.C. & Bhati R. 1998. Food preferences of some dung beetles (Coleoptera: Scarabaeidae). *J. Ent. Res*., 22(2): 107–115.

Mittal I.C. & Kakkar N. 2005. Community dynamics of dung beetles (Scarabaeidae) in a semi-arid region at Kurukshetra in Northern India. In: Gupta S.R., Matta N.K., Aggarwal A., Kohli R.K. & Chawla A.K., editors. *Ecology and environmental management: issues and research needs*, 15: 53–59. National Institute of Ecology, Jaipur and New Delhi.

Mittal I.C. & Vadhera S. 1998. Succession and community structure in dung beetles (Coleopera: Scarabaeidae) in ageing cattle dung. *J. Ent. Res*., 22(3): 253–264.

Mittal I.C. 1981. Distributional patterns in Scarabaeidae (Coleoptera): A study on north-west India. *Ent. Blatter.,* 77 (1–2): 75–85.

Mittal I.C. 1986. Dung beetles attracted to human faeces. *Ent. Blatter*., 82(1–2): 55–64.

Mittal I.C. 1993. Natural manuring and soil conditioning by dung beetles. *Tropical Ecology*, 34(2): 150–159

Mittal I.C. 2005. Diversity and conservation status of dung beetles (Laparosticti: Scarabaeidae: Coleoptera) in North India. In: Gupta S.R., Matta N.K., Aggarwal A., Kohli R.K. & Chawla A.K., editor. *Ecology and Environmental Management: Issues and Research Needs*, 43–51. National Institute of Ecology, Jaipur and New Delhi.

Mittermeier R.A., Robles-Gil P., Hoffmann M., Pilgrim J.D., Brooks T.M., Mittermeier C.G., Lamoreux J.L. & Fonseca G. 2004. *Hotspots Revisited: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions*. CEMEX, Mexico City.

Montreuil O. 1998. Analyse phylogenetique et paraphylie des Coprini et Dichotomiini (Coleoptera: Scarabaeidae). Scenario biogeographique. *Ann. Soc. Entomol. France*, 34: 135–148.

Morelli E., Gonzalez-Vainer P. & Baz A. 2002. Coprophagous Beetles (Coleoptera: Scarabaeoidea) in Uruguayan Prairies: Abundance, Diversity and Seasonal Occurrence. *Studies on Neotropical Fauna and Environment*, 37(1): 53–57.

Morón M.A., Caamal J. & Canul O. 1986. Análisis de la entomofauna necrófila del área Norte de la Reserva de Biosfera "Sian Ka'an" Quintana Roo, México. Folia Entomol. Mex 69: 83–98.

Motschulsky V. 1858. Entomologie speciale- II. Insectes des Indes orientales. I. Serie. Etudes entomologiques. *Helsingfors*, 7: 20–122 (53–57).

Murphy P.G. & Lugo A.E. 1986. Ecology of tropical dry forest. *Annual Review of Ecology and Systematics* 17: 67–88.

Myers N. 2003. Biodiversity hotspots revisited. *Bioscience*, 53: 916–917.

Nair S.C. 1991. *The Southern Western Ghats- a biodiversity conservation plan.* Indian National Trust for Art and Cultural Heritage, New Delhi, pp. 92.

Nakane T. & Shirahata K. 1957. A list of coprophagous Lamellicornia collected from Shansi, North China. *Sc. Rep. Saikyo Univ*., 2: 229–232.

Nakane T. & Tsukamoto K. 1956. On the Scarabaeidae of Japan III. (Subfamily Scaraabeinae). *Entomological Review of Japan*, 23–27.

Navarrete D. & Halffter G. 2008. Dung beetle (Coleoptera: Scarabaeidae: Scarabaeinae) diversity in continuous forest, forest fragments and cattle pastures in a landscape of Chiapas, Mexico: the effects of anthropogenic changes. *Biodiversity Conservation*, 17: 2869–2898.

Nealis V.G. 1977. Habitat associations and community analysis of South Texas dung beetles (Coleoptera: Scarabaeinae). *Canadian Journal of Zoology*, 55: 138–147.

Neves F.S., Oliveira V.H.F., Espírito-Santo M.M., Vaz-de-Mello F.Z., Louzada J., Sanchez-Azofeita A. & Fernandes F.W. 2010. Successional and seasonal changes in a community of dung beetles (Coleoptera: Scarabaeinae) in a Brazilian tropical dry forest. *Natureza and Conservação* 8: 160–164.

Newton P.N. & Malcolm J.C. 1985. Dung and dung beetles in Kanha Tiger Reserve, Central Indian highlands. *Journal of the Bombay Natural History Society*, 85: 218–220.

Nielsen S.T. 2007. Deforestation and biodiversity: effects of bushland cultivation on dung beetles in semi-arid Tanzania. *Biodivers. Conserv.,* 16: 2753–2769.

Nithya S. 2012. *Taxonomy and ecology of forest dung beetles* (*Coleoptera: Scarabaeidae: Scarabaeinae*) *in the moist south Western Ghats.* Ph.D. Thesis, University of Madras.

Noss R.F. 1990. Indicators for monitoring biodiversity: a hierarchical approach. *Conservation Biology*, 4: 355–364.

Nummelin M. & Hanski I. 1989. Dung beetles of the Kibale forest, Uganda: a comparison between virgin and managed forests. *Journal of Tropical Ecology*, 5: 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.

Ochi T. 2003. Studies on the coprophagous scarab beetles from East Asia. VII descriptions of two new subgenera of the genus *Onthophagus* (Coleoptera, Scarabidae). *Giornale Italiano di Entomologia*, 10: 259–274.

Olivier G.A. 1789. *Entomologie, ou Histoire Naturelle des Insectes*, *avec leurs caractères génériques et spécifiques*, *leur description*, *leur synonymie*, *et leur figure enluminée*. *Coléoptères*. *Tome premier*. Baudouin, Paris, xx + 433 pp. [Genera separately paginated]

Oppenheiner J.R. 1977. Ecology of dung beetles (Scarabaeidae: Coprinae) in two villages of West Bengal. *Records of the Zoological Survey of India.,* 72: 389–398.

Orris J.B. 2005. Megastat version 10.0. Butler University, College of Business Administration, 4600 Sunset Ave, Indianapolis. Distributed by McGraw-Hill. Available online: http://www.mhhe.com/support.

Osberg D.C., Doube B.M. & Hanrahani S.A. 1994. Habitat specificity in African dung beetles: the effect of soil type on the survival of dung beetle immatures (Coleoptera Scarabaeidae). *Tropical Zoology*, 7: 1–10.

Owen-Smith R.N. 1983. Management of Large Mammals in African Conservation areas. In: Owen-Smith R.N., editor. *Proceedings of a Symposium held in Pretoria, South Africa*, 29–30. HAUM, Kagiso, Pretoria.

Paarmann W. & Stork N.E. 1987. Seasonality of ground beetles (Coleoptera: carabidae) in the rain forests of N. Sulawesi. (Indonesia). *Ins. Sci. Appl.,* 8: 483–487.

Palestrini C. 1985. Note sistematiche e zoogeografiche su lun sotogener e indoafricano di Onthophagus (Coleoptera, Scaraboidea: Onthophagini). *Bull. Mus. Reg. Sci. Nat. Torino.,* 3: 29–52.

Pascal J.P. 1991. Floristic composition and distribution of evergreen forests in the Western Ghats, India. *Palaeobotanist*, 39(1): 110–126.

Paulian R. 1938. Expedition to south west Arabia (1937–1338). Coleoptera: Scarabaeidae: Troginae, Geotrupinae, Dynamopinae, Hybosorinae, Coprinae, Aphodiinae. *British Museum*, I (12): 141–155.

Paulian R. 1980. Coléoptères Scarabaeidae Canthoninae d'Inde du sud revue suisse de zoologie. *Geneve* 87(1): 57–66.

Pearson D.L. & Cassola F. 1992. World-wide species richness patterns of Tiger beetles (Coleoptera: Cicindelidae): Indicator taxon for biodiversity and conservation studies. *Conservation Biology*, 6: 376–391.

Peck S.B. & Forsyth A. 1982. Composition, structure, and competitive behaviour in a guild of Ecuadorian rain forest dung beetles (Coleoptera, Scarabaeidae). *Canadian Journal of Zoology*, 60: 1624–1634.

Peck S.B. & Howden H.F. 1984. Response of a dung beetle guild to different sizes of dung bait in a Panamanian rainforest. *Biotropica*, 16: 235–238.

Péringuey L. 1900. Descriptive catalogue of the Coleoptera of the south Africa (Lucanidae and Scarabaeidae). *Transactions of South African Philosophers Society*, 12: 1–563.

Philips K., Pretorius E. & Scholtz C.H. 2004. A phylogenetic analysis of dung beetles (Scarabaeinae: Scarabaeidae): unrolling an evolutionary history. *Inv. Syst.,* 18: 53–88.

Pineda E. & Halffter G. 2004. Species diversity and habitat fragmentation: frogs in a tropical landscape in Mexico. *Biological Conservation,* 117: 499–508.

Pineda E., Moreno C., Escobar F. & Halffter G. 2005. Frog, Bat and dung beetle diversity in the cloud forest and coffee agroecosystems of Veracruz, Mexico. *Conservation Biology,* 19 (2): 400–410.

Priyadarsanan D.R., 2006. Insecta: Coleoptera: Scarabaeoidea: Scarabaeidae (dung beetles). In: Thirumalai G. & Krishnan E., editors. *Fauna of Biligiri Rangaswamy Temple Wildlife Sanctuary: Conservation Area Series*, 27: 91–135. Published by Director Zoological Survey of India, Kolkata.

Quintero I. & Halffter G. 2009. Temporal changes in a community of dung beetles (Insecta: Coleoptera: Scarabaeinae) resulting from the modification and fragmentation of tropical rain forest. *Acta Zoológica Mexicana (nueva serie)*, 25: 625–649.

Quintero I. & Roslin T. 2005. Rapid recovery of dung beetle communities following habitat fragmentation in central Amazonia. *Ecology,* 86(12): 3303–3311.

Rajan P.D. 2006. Insecta: Coleoptera: Scarabaeoidea: Scarabaeidae (Dung beetles), Fauna of Biligiri Rangaswamy Temple Wildlife Sanctuary, Conservation Area. *Zoological Survey of India,* 27: 91–135.

Ratcliffe B.C. 1991. The scarab beetles of Nebraska. *Bulletin of the University of Nebraska State Museum*, 12: 1–333.

Reitter E. 1892. Bestimmungs-Tabelle der Lucaniden und coprophagen Lamellicornien des palaearctischen Faunengebietes. *Verh. Naturf. Ver. Brunn.,* 30: 141–262.

Ridsdill-Smith T.J. & Hall G.P. 1984a. Beetles and mites attracted to fresh cattle dung in south-western Australian pastures. *CSIRO Australia Division of Entomology Report*, 34: 1–29.

Ridsdill-Smith T.J. & Hall G.P. 1984b. Seasonal patterns of adult dung beetle activity in south-western Australia. *Proceedings of the 4th International Conference on Mediterranean Ecosystems*, 139–140. The Botany Department, University of Western Australia.

Rosenstock S.S. 1998. Influence of Gambel Oak on breeding birds in ponderosa pine forests of northern Arizona. *Condor*, 100: 485–492.

Rosenzweig M.L. 1995. *Species diversity in space and time*. Cambridge University Press. United Kingdom.

Roslin T. & Koivunen A. 2001. Distribution and abundance of dung beetles in fragmented landscapes. *Oecologia*, 127: 69–77.

Rougon D. & Rougon C. 1991. Dung beetles of the Sahel region. In: Hanski I. & Cambefort Y., editors. *Dung Beetle Ecology*, 230–241. Princeton University Press.

Sabu 2012. *Dung specificity, guild structure, seasonality and species composition of dung beetles (Coleoptera: Scarabaeinae) associated with the dung droppings of major mammals (elephant, gaur, wild boar, deer and macaque) and composition of arboreal dung beetles in the wet and dry forests of the Western Ghats*. Project report submitted to Ministry of Environment and Forests.

Sabu T.K. & Vinod K.V. 2005. Comparative assessment of the guild structure and taxonomic diversity of two beetle (Coleoptera: Scarabaeinae) assemblages in the Wayanad region of Western Ghats. In: Mary R., editor. *Proceedings of the National Conference safe environment for the future generations*, 47–52. Dept. of Zoology, Auxilium College.

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: 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 hot spot in south western India. *Journal of Tropical Conservation Science*, 4(1): 12–24, 2011.

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* H. Smith (Artiodactyla: Bovidae), from the moist deciduous forests of southern Western Ghats. *Biosystematica*, 1(1): 59–69.

Sachs L. 1992. *Angewandte Statistik*. Springer, Berlin, Heidelberg.

Scheffler P.Y. 2002. *Dung Beetle (Coleoptera: Scarabaeidae) Ecology in the Intact and Modified Landscape of Eastern Amazonia*. Ph.D. Thesis. Pennsylvania State University.

Scheffler P.Y. 2005. Dung beetle (Coleoptera: Scarabaeidae) diversity and community structure across three disturbance regimes in eastern Amazonia. *Journal of Tropical Ecology*, 21: 9–19.

Schoener T.W. 1974. Resource partitioning in ecological communities. *Science*, 185: 27–38.

Schoolmeesters P. & Sabu T.K. 2006. A new *Onthophagus* species from Kerala, India. *Phegea*, 34(2): 73–75.

Schoolmeesters P. 2011. World Scarabaeidae database, species 2000 & it is catalogue of life: 2012 Annual Checklist. Accessed on 1, December 2012. www.datascaraebaeoidea.net/Index.html.

Serville J.G.A. 1825. In Encyclopedie Methodique. *Entomologie*, 10: 1–344.

Sewak R. & Yadva V.K. 1991. Dung beetles (Coleoptera: Scarabaeidae: Coprinae) from five districts of western Uttar Pradesh. *Oikoassay*, 8: 1–2.

Sewak R. 1985. Male genitalia of some species of Catharsius Hope (Coleoptera: Scarabaeidae) and its taxonomic importance. *Journal of Animal Morphology and Physiol*ogy, 32(1–2): 269–271.

Sewak R. 1986. Male genitalia of Indian Onthophagus Latr. (Coleoptera: Scarabaeidae) and its taxonomic importance. *Journal of Animal Morphology and Physiol*ogy, 33(1–2): 135–140.

Sewak R. 1988. Male genitalia of Indian Oniticellus Serville (Coleoptera: Scarabaeidae) and its taxonomic importance. *Journal of Animal Morphology and Physiol*ogy, 35(2): 165–168.

Sewak R. 2004. Insecta: Coleoptera: Scarabaeidae: Coprinae (dung beetles). Fauna of Gujarat, state fauna series. *Zoological Survey of India*, 8:105–125.

Sewak R. 2006. Insecta: Coleoptera: Scarabaeidae: Coprinae (dung beetles). Fauna of Arunal Pradesh, state fauna series. *Zoological Survey of India*, 13 (2): 191–224.

Shahabuddin. 2010. Diversity and community structure of dung beetles (Coleoptera: Scarabaeidae) across a habitat disturbance gradient in Lore Lindu National Park, Central Sulawesi. *Biodiversitas*, 11(1): 29–33.

Shahabuddin. 2011. Effect of land use change on ecosystem function of dung beetles: Experimental evidence from Wallacea Region in Sulawesi, Indonesia. *Biodiversitas*, 12(3): 177–181.

Shahabuddin, Schulze C.H. & Tscharntke T. 2005. Changes of dung beetle communities from rainforests towards agroforestry systems and annual cultures in Sulawesi (Indonesia). *Biodiversity conserv.,* 14: 863–877.

Shannon C.E. & Weaver W. 1949. *The Mathematical Theory of Communication*. University of Illinois Press, 117 pp.

Shipp J.W. 1897. On the genus *Gymnopleurus*, Illiger; with a list of species and descriptions of two new genera. *The Entomologist* XXX: 166–167.

Siddiqui H., Ahmed Z. & Khatri I. 2014. Distributional Notes and New Records for the Dung Beetles of Pakistan Pakistan. *Journal of Zoology*, 46(2):295–307.

Simpson E.H. 1949. Measurement of diversity. *Nature*, 163:688.

Skole D. & Tucker C.J. 1993. Tropical deforestation and habitat. Fragmentation in the Amazon: satellite data from 1978 to 1988. *Science,* 260: 1905–1910.

Smith A.B.T. 2003. Checklist of the Scarabaeoidea of the Nearctic Realm. University of Nebraska, Lincoln.

Sowig P. & Wassmer T. 1994. Resource partitioning in coprophagous beetles from heep dung: phenology and microhabitat preferences. *Zool. Jb. Syst*., 121: 171–192.

Spector S. & Ayzama S. 2003. Rapid turnover and edge effects in dung beetle assemblages (Scarabaeidae) at a Bolivian Neotropical forest- savanna ecotone. *Biotropica*, 35(3): 394–404.

Spector S. & Forsyth A.B. 1998. Indicator taxa for biodiversity assessment in the vanishing tropics. In: Mace G., Balmford A. & Ginsberg R., editors. *Conservation in a Changing World*, 181–209. Cambridge University Press, Cambridge, UK.

Tarasov S.I. 2010. Seven new synonyms within the genus *Onthophagus* (Coleoptera: Scarabaeidae) from the Oriental Region. *Zootaxa* 2566: 45–48.

Thomson C.G. 1863. Skandinaviens Coleoptera. Synoptisk bearbetade.

Tshikae B.P., Davis A.L.V. & Scholtz C.H. 2008. Trophic associations of a dung beetle assemblage (Scarabaeidae: Scarabaeinae) in a woodland savanna of Botswana. *Environmental Entomology*, 37(2): 431–441.

Valencia G., Alonso A., Dallmeier F. & Campbell P. 2001. Diversity and Trophic Relationships of Dung Beetles of the Lower Urubamba Region, Peru. Urubamba: The Biodiversity of a Peruvian Rainforest. Smithsonian Institution, Washington, DC.

Vaz-de-Mello F.Z. 2003. *Ochicanthon*, a new name for *Phacosoma* Boucomont (Coleoptera, Scarabaeidae), preoccupied with *Phacosoma* Jukes-Browne (Mollusca). *Coleopterists Bulletin*, 57: 25–26.

Veenakumari K. & Veeresh G.K. 1996a. Notes on the feeding and breeding behaviour of *Gymnopleurus gemmatus* Harold and *Gymnopleurus miliaris* (Fabricius) (Coleoptera: Scarabaeidae). *Journal of the Bombay Natural History Society*, 93: 13–19.

Veenakumari K. & Veeresh G.K. 1996b. Some aspects of the reproductive biology of *Onthophagus gazella* (F.) and *Onthophagus rectecornutus* Lansb. (Coleoptera: Scarabaeidae). *Journal of the Bombay Natural History Society*, 93: 250–256.

Veenakumari K. & Veeresh G.K. 1997. Subsociality in dung beetles of *Copris repertus* Walker and *Copris indicus* Gill (Coleoptera: Scarabaeidae). *J. Bombay Nat. Hist. Soc.,* 94: 530–535.

Veiga C.M., Lobo J.M. & Mart´ın-Piera F. 1989. Lastrampas pitfall con cebo, sus posibilidades en el studio de las comunidades copr´ ofagas de

Scarabaeoidea (Col.) II: An´alisis de efectividad. *Rev. Ecol. Biol. Sol.*, 26: 91–109.

Vernes K., Pope L.C., Hill C.J. & Barlocher F. 2005. Seasonality, dung specificity and competition in dung beetle assemblages in the Australian Wet Tropics, north-eastern Australia. *J. Trop. Ecol*., 21: 1–8.

Vinod K.V. & Sabu T.K. 2007. Species composition and community structure of dung beetles attracted to dung of gaur and elephant in the moist forests of south Western Ghats. *Journal of Insect Science*, 7: 1–56.

Vinod K.V. 2009. *Studies on the Systematics and Distribution of Dung Beetles (Scarabaeinae: Coleoptera) in the Forests and Agricultural Fields of Wayanad.* Ph.D. Thesis, Forest Research Institute University, Dehradun, 214 pp.

Vulinec K., Lambert J. & Mellow D.J. 2006. Primate and dung beetle communities in secondary growth rainforests: Implications for conservation of seed dispersal systems. *International Journal of Primatology*, 27: 855–879.

Vulinec K. 2000. Dung beetles (Coleoptera: Scarabeiadae), monkeys and conservation in Amazonia. *Florida Entomologist*, 83: 229–241.

Waage J.K. & Best R.C. 1985. Arthropod associates of Sloths. In: Montgomery G.G., editor. *The Evolution and Ecology of Armadillos, Sloths and Vermi linguas*, 319–322. Smithsonian Institution.

Walker F. 1858. Characters of some apparently undescribed Ceylon Insects. *Annals and Magazine of Natural History*, 3(2): 202–209

Walter P. 1985. Diurnal and nocturnal flight activity of Scarabaeine coprophages in tropical Africa. *Revue internationale de géologie, de géographie et d'écologie tropicales*, 9: 67–87.

Waterhouse C.O. 1891. V- New Scarabaeidae in the British Museum: 5th contribution. *The Annals and Magazine of Natural History, including Zoology, Botany and Geology*, 6(8): 53–60.

Weber F. 1801. Observationes Entomologicae. Impensis Bibliopolii Academici Novi. Panama. *J. Anim. Ecol.*, 50: 827–838.

Whitmore T.C., Sayer J.A. 1992. *Tropical deforestation and species extinction.* London, UK: Chapman & Hall.

Wiedemann C.R.W. 1823. Zweihundert neue Käfer von Java, Bengalen und dem Vorgebirge der guten Hoffnung (Wiedemann). *Zoologisches Magazin*, 2(1): 1–133.

Wikramnayake E., Dinerstein E., Loucks C.J., Olson D.M., Morrison J., Lamoreux J., McKnight M. & Hedao P. 1999. *A biodiversity Assessment and Gap analysis of the Himalayas*, Washington, DC: World Wildlife Fund.

Wolda H. & Estribi M. 1985. Seasonal distribution of the large sloth beetle Uroxys gorgon Arrow (Scarabaeidae: Scarabaeinae) in light traps in Panama. In: Montgomery G.G., editor. *The evolution and ecology of armadillos, sloths and vermilinguas*, 319–322. Smithsonian Institution Press, Washington D.C.

Wolda H. 1978. Seasonal fluctuations in rainfall, food and abundance of tropical insects. *J. Anim. Ecnl.*, 47: 369–381.

Wolda H. 1988. Insect seasonality: why? *Annual review of ecology and systematics* 19: 1–18.

Woodruff R.E. 1973. The scarab beetles of Florida (Coleoptera: Scarabaeidae). Part 1. The Laparosticti (subfamilies Scarabaeinae, Aphodiinae, Hybosorinae, Ochodaeinae, Geotrupinae, Acanthocerinae). Arthropods of Florida and Neighboring land areas. *Florida Dept. Agric. Cons. Serv.*, 8: 1–220.

Wright K.L. 1997. *An Examination of the Commensal Interaction between the Australian Native Bung Beetle, Onthophagus peramelinus and the Rufous Bettong, Aepyprymnus rufescens*. B.Sc. Dissertation. James Cook University.

WWF 2008. South Western Ghats Landscape. Accessed on May7, 2009. http://www.wwfindia.org/about_wwf/what_we_do/forests/western_ghats/.

Young O.P. 1981. The attraction of Neotropical Scarabaeinae (Coleoptera: Scarabaeidae) to reptile and amphibian fecal material. *Coleopterists Bulletin*, 35(3): 345–348.

Zunino M. 1979. Gruppi artificiali e gruppi naturali negli Onthophagus (Coleoptera, Scaraboidea). *Boll. Mus. Zool. Univ. Torino.*, 1:1–18.

Zunino M. 1981. Insects of Saudi Arabia. Coleoptera: family Scarabaeidae, tribe Onthophagini. *Fauna of Saudi Arabia*, 3: 408–416.

Zunino M. 1983. Essai préliminaire sur Ìévolution des armatures genitales des Scarabaeinae, par rapport a` la taxonomie du groupe et à Ìévolution du comportement de nidification (Col. Scarabaeidae). *Bulletin de la Societe Francaise d'Entomologie*, 88: 531–542.

Zunino M. 1984. Analisi sistematica e zoogeografica della sottofamiglia Taurocerastinae Germain (Coleoptera, Scarabaeoidea: Geotrupidae). *Dal Boll. Mus.Reg. Sci. Nat. Torino*, 2: 445–464.

LIST OF PLATES

LIST OF FIGURES

LSIT OF TABLES

LIST OF SYMBOLS AND ABBREVIATIONS

'#'= first report from India and Western Ghats

'@'= endemic to the Western Ghats

'*'= rare in the region

Di= diurnal

N= nocturnal

G= generalist

Dw= dweller

R= roller

T= tunneler

SE= seasonal

AS= aseasonal